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UNITED STATES MARINE CORPS
ASSAULT AMPHIBIAN VEHICLE EGRESS STUDY

by

Jason T. Ford

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Thesis Advisor:	Lawrence G. Shattuck
Second Reader:	Lyn R. Whitaker

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Jason T. Ford
Major, United States Marine Corps
B.S., United States Naval Academy, 2000

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June 2014

Author: Jason T. Ford

Approved by: Lawrence G. Shattuck
Thesis Advisor

Lyn R. Whitaker
Second Reader

Robert F. Dell
Chair, Department of Operations Research

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ABSTRACT

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LIST OF ACRONYMS AND ABBREVIATIONS

A2/AD:	Anti-Access/Area Denial
A2C2S:	Airborne Command and Control System
AASB:	Assault Amphibian School Battalion
AAV:	Assault Amphibian Vehicle
ACV:	Amphibious Combat Vehicle
ANOVA:	Analysis of Variance
AVTB:	Amphibious Vehicle Test Branch
BNO:	Battalion Order
C3:	Command, Control and Communications
CAD:	Computer-aided Design
CFT:	Combat Fitness Test
DoD:	Department of Defense
EAS:	Emergency Air Supply
EFV:	Expeditionary Fighting Vehicle
ETB:	Embarked Troop Brief
FMC:	Food Machinery Corporation
FOS:	Feasibility of Support
FY:	Fiscal Year
HEDGE:	Human Factors Engineering Data Guide for Evaluation
HESP:	Helicopter Egress System for Passengers
HFE:	Human Factors Engineering
HSD:	Honestly Significant Difference
HSI:	Human Systems Integration
IED:	Improvised Explosive Device
JMP:	John's Macintosh Project
LVT:	Landing Vehicle Tracked
LVTP-7:	Landing Vehicle Tracked Personnel, Model 7
MAGTF:	Marine Air Ground Task Force
MANPRINT:	Manpower and Personnel Integration
MCCDC:	Marine Corps Combat Development Command

MCWP:	Marine Corps Warfighting Publication
MEU:	Marine Expeditionary Unit
MOPP:	Mission Oriented Protective Posture
MOS:	Military Occupational Specialty
MPC:	Marine Personnel Carrier
OMFTS:	Operation Maneuver from the Sea
PEO LS:	Program Executive Office Land Systems
PFD:	Personal Flotation Device
PFT:	Physical Fitness Test
PM AAA:	Program Manager Advanced Amphibious Assault
RAH-66:	Reconnaissance Attack Helicopter-66
RAM/RS:	Reliability Availability and Maintainability/Rebuild to Standard
SAW:	Squad Automatic Weapon
SDD:	System Development and Demonstration
SE-OPT:	System Evaluation Operational Planning Team
SLEP:	Service Life Extension Program
SME:	Subject Matter Expert
SOP:	Standard Operating Procedure
SOW:	Statement of Work
STOM:	Ship to Objective Maneuver
TIS:	Time in Service
TOD:	Time of Day
TOP:	Test Operations Procedure

EXECUTIVE SUMMARY

Due to the discontinuation of the Expeditionary Fighting Vehicle, the Marine Corps is studying a new Amphibious Combat Vehicle (ACV) to replace the 42-year-old Assault Amphibian Vehicle (AAV). The ACV is projected to enter service in 2022 with full implementation occurring by 2030. In the interim, the AAV will remain the Marine Corps' forcible entry platform with survivability upgrades designed to extend its use until the ACV's implementation. While the Marine Corps is assessing various components of the legacy AAV, this thesis assessed the emergency egress time and associated standard operating procedures. Future modifications may alter the buoyancy characteristics significantly, changing the way the AAV sinks and thus the way Marines must egress. To provide a point of reference for the modified AAV and the future ACV, we established benchmark egress and evacuation times.

In August 2012, we performed a full factorial experiment at Amphibious Vehicle Test Branch (AVTB) in Camp Pendleton, CA. Our experiment subjected infantry to 216 time trials with variables that included 17 vs. 21 embarked infantry, daylight vs. restricted light conditions, three combinations of armor and personal flotation device, and six routes of egress or evacuation. Additionally, we measured each Marine and analyzed the anthropometric data to ensure that our subjects were a representative sample of the Marine Corps infantry population. At the conclusion of the experimentation, we surveyed each Marine to gain additional insight.

We used analysis of variance (ANOVA) and descriptive statistics to identify specific factor combinations that yielded the lowest egress times. Subjects egressed from the AAV with an average time of 1:39 (98.78 seconds) and a median time of 1:17 (76.6 seconds). The range was 0:29 (28.7 seconds) to 6:10 (370 seconds) with a standard deviation of 1:01 (61.41 seconds). When subjects had the ability to egress through all available hatches, their egress times

decreased significantly. In fact, the most significant factor in decreasing egress times is the route.

Further, when subjects dropped their weapons and body armor, egress times reduced dramatically; this was especially true when the route combination forced the subjects through the forward hatches only. Daylight and 17-subject configurations also had some minor effects on reducing the group's time. The LPU-41/SRU-43 HESP, while having a unique emergency air canister, created more snags and limited each subject's ability to egress, especially subjects who fell in the 95th percentile for several anthropometrics. Unlike the older LPU-32, the HESP did not fit underneath the subjects' armor; therefore, it prevented subjects from shedding their gear during egress or evacuation.

The research revealed that the vehicle commander would benefit from an SOP that is more permissive. In the event of a slow sink, the situation may quickly deteriorate into a rapid sink. The vehicle commander should be able to make the call to remove gear at any time to save the lives of Marines.

If buoyancy characteristics change the manner in which an AAV sinks, then three recommendations remain. First, ensuring all potential routes are operable in the event of an emergency egress will ensure maximum survivability of the entire crew and all passengers. Second, use of a personal flotation device that does not restrict the removal of body armor will reduce snags and blockages. Third, survival during waterborne operations requires realistic training, simple instructions, and up-to-date procedures. Developing a doctrine that captures the institutional knowledge of the Marine Corps would serve to enhance training and to reduce potential incidents related to emergency egress. This thesis provides baseline data for future emergency egress studies on the AAV and the new ACV.

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Thanks to the Marines at Camp Pendleton, specifically at Amphibious Vehicle Test Branch. Their dedication and professionalism was motivating. Thanks to my cohort who assisted me through two years of operations analysis. Thanks to my little girl and my lovely wife who stood by me patiently, throughout the entire process.

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I. INTRODUCTION

A. PROBLEM STATEMENT

The United States Marine Corps has projected forces ashore in the form of amphibious landings for the last 237 years. The Marine Corps has a rich history of being “soldiers from the sea,” especially when it comes to amphibious operations. From the Raid of Nassau (Hoffman, 2002) to the demonstration during the Persian Gulf War (Hayden, 1995), Marines have built a remarkable reputation accomplishing the mission that defines their very name. Despite the Wars in Iraq and Afghanistan, the Marine Corps is determined to eliminate the notion of being a “second land army” and get back to its maritime roots (Amos, 2011). With increased U.S. emphasis on the Pacific Theater of Operations (Defense Strategic Guidance, 2012), the Marine Corps sees its current doctrine, training and equipment, with respect to its premier core competency, as insufficient.

The AAV Egress Study focuses on the emergency egress from an AAV for a full complement of subjects. The study uses experimentation and quantitative analysis to address proposed equipment modifications and modify operating procedures. The analysis yields the importance of each factor relative to the process of egress. It also exposes which levels of those factors contribute to increased or decreased overall egress time. Shifting focus towards the Pacific, many nations look to reinforce their littoral regions with anti-access/area denial (A2/AD) measures. A2/AD is a state’s ability to control its cyber and physical space while denying potential adversaries access to that same space (Defense Strategic Guidance, 2012). Advancing A2/AD capabilities require the United States to remain in the lead with regard to forcible entry. Forcible entry into the littoral regions requires the ability to conduct opposed amphibious landings. The nation’s first choice for opposed amphibious landings is the Navy-Marine Corps

team, and the Marine Corps' tool of choice is the Assault Amphibian Vehicle (AAV).

For the past 42 years, the AAV has been the workhorse of Marine Corps' amphibious operations. The AAV was scheduled for replacement by the Expeditionary Fighting Vehicle (EFV) but Congress canceled the EFV program at the beginning of 2011 at the direction of Secretary of Defense Robert Gates and Commandant of the Marine Corps General James Amos. The Amphibious Combat Vehicle (ACV) is now scheduled to replace the AAV but has a projected operational timeframe between FY2020 and FY2022. This makes the already overworked AAV the stopgap system for the near future.

To meet immediate operational requirements, the Marine Corps decided the AAV must undergo a survivability upgrade. Although specifics have not been fully determined to date, the upgrade is expected to improve the performance of the AAV on both land and water. This increased performance will undoubtedly lead to a change in the characteristics of the AAV's reserve buoyancy and overall waterborne attributes. These changes will, in turn, alter the survivability of subjects attempting to egress from a sinking AAV. For decision makers to assess risk appropriately, a current survivability baseline needs to be established.

This study analyzes time trials conducted at Camp Pendleton in August 2012 to establish the time it takes the subjects of a fully loaded AAV (17 or 21 combat-loaded infantry plus three crewmen) to egress under various conditions and scenarios. Additionally, the statistical analysis of egress data will inform revisions of the standard operating procedures (SOPs) and increase the probability of survival.

B. OBJECTIVES

In August of 2011, a System Evaluation Operational Planning Team (SE-OPT) convened to address the "road ahead" for the AAV and future systems (H. Oldland, personal communication, 25 April 2013). The SE-OPT produced several initiatives, one of which was a statement of work (SOW) that outlined the need to

conduct an egress study. The SOW described several factors and two different sink scenarios for testing. The egress study's primary objectives were as follows (SOW, 2011):

- Establish the time it takes for 17 or 21 embarked Infantry and crew to egress during a rapid sink scenario; and
- Establish the time it takes for 17 or 21 embarked Infantry and crew to egress during a slow sink or disabled vehicle scenario.

C. RESEARCH QUESTIONS

The SOW's developers sought data that would quantify emergency egress from a sinking AAV. These data would be used in equipment and SOP modification process. The following research questions were derived from the SOW and provided focus for the experimental design, data collection, and subsequent analysis:

1. What factors provide subjects in a sinking AAV the best chance for survival?
2. Is the design of experiment appropriate given the safety constraints?
3. Does the current SOP establish the optimal settings for maximum survivability of an embarked crew and subject load during waterborne operations?

D. THEORETICAL FOUNDATIONS

On 13 January 2011, Sergeant Wesley Rice drowned in a sinking AAV. The accident occurred while conducting a training exercise in the Del Mar boat basin at Camp Pendleton, California (Kovach, 2011). The event was reminiscent of a similar accident that resulted in a fatality in 1994. During the more recent accident, the vehicle entered the water with all three crew hatches open and the bow plane in the down position. When the vehicle sped up, the nose sank, which allowed water to flow into the crew hatches and pinned the crewmen inside. However, because the cargo hatches remained secured, the subjects in the back remained unaware of the impending danger. The vehicle commander ordered

Sergeant Rice (the third crewman in the back) and the other two subjects to engage the fuel shut-off valve and prepare to evacuate. The crew chief then swam to the surface. The other two subjects evacuated while Sergeant Rice tended to the shut-off valve. At some point, Sergeant Rice suffered a head injury and was unable to escape. Of the five subjects who sank with the AAV during this training exercise, only four were able to swim to the surface (J. Accord, personal communication, 6 August 2012). Setting aside the obvious errors in procedure, the accident illustrates the dynamic nature and inherent danger associated with waterborne movement in an AAV.

The AAV is the primary tool to gain access into an opposed coastal region where the enemy has the advantage of terrain and is employing mines and direct fire weapon systems. Under such conditions, the possibility of sinking with a full complement of Marines in the back of an AAV becomes eerily plausible. Therefore, it is important for decision makers to know what factors could prevent those Marines from drowning. However, it is extremely difficult to determine with precision what factors affect egress from a sinking AAV because of the inherent complexities in such circumstances.

> It is well noted that accidents are generally the result of situations that a given system is not able to handle…emergency situations can create interactive conditions that have not been fully predicted nor modeled. Problems increase dramatically when the environment becomes toxic from fire and smoke. In sum, there is potentially no end to the complexity that [a vehicle] accident might embody, and consequently, no end to the number or quality of interactions that can be imagined to exist in these scenarios. (McLean, 2001, p. 1)

Human Factors Engineering (HFE) is “the study of those variables that influence the efficiency with which the human performer can interact with the inanimate components of a system to accomplish the system goals” (Proctor & Van Zandt, 2008, p. 10). Although there is an obvious human system interaction taking place in all phases of AAV operation, this study is concerned with human performance when the vehicle begins to sink. Specifically, the system is the

sinking AAV, and the desired human performance is the safe egress of every subject. There are several methods used to measure human factors. This study uses descriptive and experimental methods.

Descriptive methods involve analyzing situations in their natural or real-world setting. The strength of this method is that the "concern of human factors is the operation system, which by its nature is complex and not subject to precisely controlled investigation" (Proctor & Van Zandt, 2008, p. 33). This poses several significant problems for the egress study. Due to safety concerns, floating an AAV in the water and conducting egress experiments places the test subjects at considerable risk and creates a significant logistical burden when trying to perform multiple trials.

Two critical considerations exist when using experimental methods: internal validity and ecological validity. Internal validity exists when the outcome of an experiment can be repeated. However, the strict control of laboratory experiments can have a "dilution effect," causing low ecological validity (Proctor & Van Zandt, 2008, pp. 33, 38). This is not to say that experimental methods are not useful. "… [F]actorial studies implemented to illuminate the contributions to system function or an individual factor(s) and the interactions it produces with another factor(s) provide a basis for understanding the total system and its functions" (McLean, 2001, p. 2).

This egress study stayed within the limitations of safety, and therefore, relied on a combination of descriptive and experimental methods to draw its conclusions. The use of a full factorial design ensured systematic study of the relevant system characteristics. "Factorial experimentation is highly efficient, because every observation supplies information about all the factors included in the experiment" (Snedecor & Cochran, 1967, p. 339).

E. THESIS ORGANIZATION

There are six chapters in this thesis. Chapter I provides a brief introduction and overview. Chapter II is a literature review with a brief history of Marine Corps

amphibious operations, the lineage of the AAV and the "road ahead." Additionally, this chapter looks at several relevant studies that provide insight into the way to conduct an egress study and concludes with research hypotheses. Chapter III describes the methods utilized in the experiment and the operational planning necessary to coordinate the event. Chapter IV describes the quantitative data analysis conducted after the experiment. Chapter V discusses the results as they relate to the research questions. Chapter VI provides a conclusion and recommendations for future work.

II. LITERATURE REVIEW

A. OVERVIEW

The literature review in this chapter consists of three distinct sections. The first section presents a brief history of Marine Corps amphibious operations and provides a detailed discussion about current geo-political relevance. The second section reviews the current status of the AAV program and the challenges associated with fielding a replacement. The third section reviews studies related to the field of emergency egress and describes the hypotheses used for the AAV Egress Study.

B. BACKGROUND

The Background section gives a brief history of Marine Corps amphibious operations and provides a detailed discussion about current geo-political relevance.

1. History of Amphibious Operations

The Marine Corps has been projecting forces ashore in the form of amphibious landings for the last 237 years. On 3 March 1776, the Continental Marines, led by Captain Samuel Nicholas, landed in the Bahamas at New Providence Island and seized Fort Montagu (Hoffman, 2002). This was the first of many Navy-Marine Corps amphibious assaults on foreign controlled land. During the Mexican-American War, Marines once again conducted amphibious landings along the coast of Mexico and California. On 7 July 1846, Marines landed at Monterey, near the pier at Fisherman’s Wharf and declared California to be part of the United States (Hoffman, 2002). Gates reported the following Marine Corps developments during the early part of the 20th Century:

> During the 1920s and 1930s, the Marine Corps conducted what would now be called stability operations in the Caribbean, wrote the Small Wars Manual and at the same time developed the

> amphibious landing techniques that would help liberate Europe and the Pacific in the following decade. (Gates, 2009, p. 7)

In November 1943, 2nd Marine Division made an assault on the Tarawa Atoll, marking the first time the Landing Vehicle Tracked (LVT) platforms were employed as amphibian troop carriers (Hoffman, 2002). The LVT was a family of vehicles used to move equipment ashore (and even became involved in some limited offensive engagements) as the Marines stormed the Japanese-controlled islands throughout the Pacific.

On 15 September 1950, General Douglas MacArthur executed an amphibious landing at Incheon, South Korea, with U.S. Marines as the majority of his troop force. Heinl described the landing as “one of the most dramatic such transitions from defense to attack in the annals of war” (Heinl, 1998, p. 117). In the Persian Gulf War, General Norman Schwarzkopf used the threat of a Marine amphibious landing to fix six Iraqi divisions to the Kuwaiti coast. The amphibious demonstration (or feint) was the greatest amphibious force assembled since Incheon and was successful in fooling and subsequently flanking the Iraqi divisions (Hayden, 1995).

2. Navy-Marine Corps Team

Throughout its history, the Marine Corps has relied heavily on its partner, the United States Navy. Operation Maneuver from the Sea (OMFTS) is the current doctrine guiding Navy-Marine Corps amphibious operations. The doctrine plainly states:

> In the absence of an adjacent land base, a sustainable forcible entry capability that is independent of forward staging bases, friendly borders, overflight rights, and other politically dependent support can come only from the sea. (Operational Maneuver from the Sea, 1996, p. 3)

There are several ways the Navy can conduct Ship to Objective Maneuver (STOM) for a Marine Air Ground Task Force (MAGTF). Utilizing amphibious shipping such as Landing Helicopter Dock (LHD), Landing Helicopter Assault

(LHA) and Landing Platform Dock (LPD), the Navy can deliver Marines and equipment ashore with landing crafts or aerial assets. (See Appendix A for platform descriptions.) However, the only system capable of making a forcible entry on an enemy-controlled beach is the AAV. The AAV can travel two nautical miles in Sea State Three (see Appendix B for Sea State Tables) and conduct an opposed landing. However, the proliferation of cruise missiles poses a significant concern to large naval ships (Gates and Mullen, 2011). In the event AAVs need to deliver Marines, amphibious ships would be in danger within 200 nautical miles of an enemy-controlled shore that possessed cruise missiles or other A2/AD technologies.

A discussion involving the tradeoff between the standoff distance the Navy requires and the range of the AAV is ongoing and will undoubtedly influence potential replacements for the Marine Corps' primary amphibian vehicle. On 11 March 2013, National Security Advisor Tom Donilon said, "The strategic pivot toward the Asia-Pacific region will help to rebalance the projection and focus of U.S. power" (Lyle, 2013, p. 1). As the nation looks to initiate a "Pacific Pivot," the U.S. will increase its naval fleet operating in the Pacific to 60% by 2020 (Lyle, 2013).

Once ashore, AAVs are directed to continue to carry the infantry and work alongside tanks as the fight moves inland. Current AAVs and their future replacements will require the mobility and armor to co-exist with tanks. Marines at times have served to augment the Army's occupation of a hostile territory for an extended period. Historic examples include Vietnam and most recently the conflicts in Iraq and Afghanistan.

Although the AAV was designed to conduct amphibious landings, there exists a requirement to remain versatile as the conflict pushes inland or when Marines are augmenting conventional ground forces. Recent conflicts have shown an increase in non-state actors utilizing improvised explosive devices (IEDs). Unfortunately, it is challenging to combine a hydrodynamic hull structure with an IED resistant design. At a minimum, the design outcome would be far

heavier than any current Navy transport could support, and would exceed the Marine Corps' ground vehicle budget. As the war in Afghanistan continues to draw down, the Marine Corps has begun to consider the future of its force and the equipment necessary to meet future threats and missions.

The Food Machinery Corporation (FMC) originally designed the LVT in 1932 to perform rescue operations in swampy terrain. Donald Roebling (grandson of John Augustus Roebling, the builder of the Brooklyn Bridge), designed the LVT-1 for operations in WWII. Over the years, the LVT went through several versions increasing its speed, power and weaponry (Hoffman, 2002). By the Vietnam War, the Marine Corps employed the LVT-5, FMC redesigned the aging LVT-5 in the 1960s. In 1967, the first pilot vehicles known as the LVTPX12 began the evaluation process with full operational service beginning in 1972 (ROC NO. MOB1.13A, 1985). It was designated the Landing Vehicle Tracked Personnel, Model 7 (LVTP-7) and was designed to carry a full complement of 25 combat-ready Marines or 10,000 lbs of cargo (ROC NO. MOB1.13A, 1985). The LVTP-7 underwent its first service life extension program (SLEP) in 1983. Re-designated in 1987 as the AAVP7A1, it received product improvement upgrades to lethality, survivability, and communications (PEO LS Industry Day Brief, 2011). Figure 1 provides a timeline from the first fielding to present day.

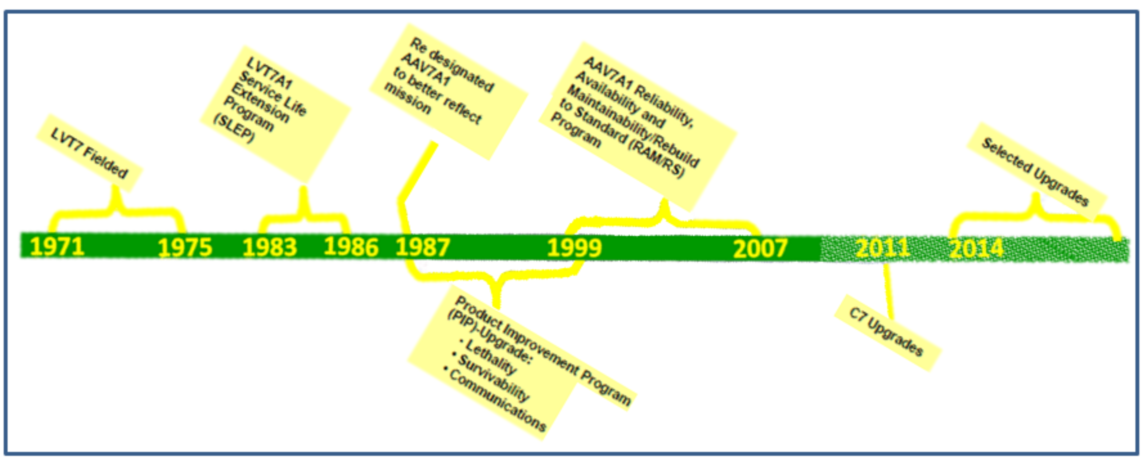

Figure 1. Timeline of LVT7/AAV7 (from PEO LS, 2011)

From 1999 to 2007, the AAV entered the Reliability Availability and Maintainability/Rebuild to Standard (RAM/RS) Program. As a result of numerous upgrades, the embarked troop capacity decreased from 25 to 21 combat-loaded Marines (Marine Corps Warfighting Publication 3-13, 2005). (See Appendix C for dimensions.) Over the years, improvements in the engine, suspension and armor made the AAV heavier and increased its nose-first sink characteristic. The increased size of the engine encroached into the troop compartment. Additionally, the average Marine has grown over the years from 160 lbs to 178 lbs (Corner & Gordon, 2008), and the personal body armor equipment weighs 88 lbs (Broadbent et al., 2009). The reduction in space combined with the increases in weight per subject directly affected the doctrinal troop capacity of the AAV over the years (K. Moore, personal communication, 11 May 2013).

In 2011, a portion of the AAV fleet received communications and survivability upgrades costing $1.7M per vehicle (Oldland, 2013). Since the EFV program’s cancellation, the percentage of the AAV fleet to undergo the upgrade has been increased. The main effort for the current upgrade is on survivability for the crew and improvements to water and land performance. Several of the proposed survivability upgrades include underbelly protection, armor protection, spall liner and blast attenuating seats. An updated command, control and communications (C3) system is also being added, along with an improved propulsion system and transmission in order to move the heavier version faster both on land and in the water (PEO LS, 2011).

C. Present Situation

The Present Situation section reviews the current status of the AAV program and the challenges associated with fielding a replacement.

1. Equipment Conflicts

In January 2011, Secretary of Defense Gates and Marine Corps Commandant General Amos recommended that Congress cancel the EFV

program. In the same speech, Secretary Gates reaffirmed the Marine Corps would retain the mission of amphibious landings.

> This decision does not call into question the Marines' amphibious assault mission. We will budget the funds necessary to develop a more affordable and sustainable amphibious tractor to provide the Marines a ship-to-shore capability into the future. The budget will also propose funds to upgrade the existing amphibious vehicle fleet with new engines, electronics and armaments to ensure that the Marines will be able to conduct ship-to-shore missions until the next generation of systems is brought online. (Gates & Mullen, 2011)

Leading up to the cancellation, the General Dynamics Corporation, the EFV lead contractor, had gone over budget and was eight years behind schedule. By then, General Dynamics needed $3.5 billion, in addition to the $8.5 billion already spent, and several more years to complete just 573 EFVs. This figure was a nearly 50% reduction from the original 1,025 EFVs ordered. Further, the EFV design did not include the V-shaped hull that recent mine resistant vehicles use to lessen the blast impact from IEDs (Feickert, 2011). An IED resistant hull structure would have made the vehicle even heavier and more expensive. Secretary Gates, understanding the rising cost of the EFV compared to the Marine Corps' total ground vehicle budget, decided to terminate the program altogether (Feickert, 2011).

Immediately following the cancelation of the EFV, Lieutenant General George Flynn, Commanding General Marine Corps Combat Development Command (MCCDC), established a System Evaluation Operational Planning Team (SE-OPT). The purpose of the SE-OPT was to review the technology already developed for the EFV and determine how to leverage it in the procurement of the Amphibious Combat Vehicle. In short, the SE-OPT, formed to answer the question: What went wrong with the EFV and how do we fix it for the next Marine Corps amphibious vehicle?

The SE-OPT consisted exclusively of engineers within the Marine Corps; it was not open to industry. The discussions spanned a wide range of issues involving the procurement of the ACV and the stopgap upgrades necessary to

sustain the AAV until fiscal year 2022 (FY22). The SE-OPT drafted several statements of work (SOW) to investigate concerns about AAV sink rates as a result of the upgrades to the system.

Two main concerns emerged from the SOWs: reserve buoyancy and emergency egress. Reserve buoyancy is “that part of the volume of a vessel that is above the water surface and is watertight” (Hoyt, 2012, p. 1). Discussion about the percentage of reserve buoyancy required for survivability and lethality remain ongoing. A technical memorandum drafted in August 2012 best described the relationship between reserve buoyancy and emergency egress:

> **Time To Sink–**A vehicle with a hull breech will take on water at a rate dictated by the size of the hole and its depth. If the breech exceeds the capacity of the bilge system, the craft will sink. The time from hull breech to sinking is determined by the net rate of water shipping onboard and the initial reserve buoyancy. As an example, a 2 inch diameter hole in the bottom of an AAV with 30% reserve buoyancy and 2 bilge pumps operating would sink in 26 minutes, however starting with only 10% reserve buoyancy would sink in 5 minutes. The question is how much time is required to safely evacuate both the troops and crew and what level of reserve buoyancy allows this. (Hoyt, 2012, p. 4)

2. The Road Ahead

The conflicts in Iraq and Afghanistan suggest that a mechanized amphibious assault capability may not be realistic in the near future of warfare for two reasons. First, the purpose of amphibious operations is to provide a foothold in the littoral regions, a responsibility easily distributed among other platforms already in the arsenal. For instance, modern day ship-to-shore connectors provide high speed and capacity lift for the bulk of the landing force through air and sea modes. The Air Force possesses huge airlift capabilities for rapid buildup of troops and equipment. The need for an armored ship-to-shore connector would only be required for an opposed landing. Once a beachhead is established, the armored vehicles secure the area while the other modes insert the remaining forces. Second, the rise of non-state actors conducting insurgencies using guerilla-style tactics requires a modular landing force. In line

with the previous example, after securing the beachhead, the landing force must be mobile and have a mine resistant capability. If that vehicle is too heavy and cannot withstand IEDs, it becomes a liability.

This viewpoint led to several alternatives for how to proceed with the Marine Corps' amphibious assault capability. First, General Dynamics proposed reducing the number of EFVs to 200 at a cost savings of $6 billion. Second, the Marine Corps announced an ACV program. The ACV needed to have the following capabilities: travel 12 miles ship-to-shore (EFV was intended to travel 25 miles); IED resistant; carry 17 combat-loaded troops; and keep up with mechanized units (M1A1 Tank) once ashore (Feickert, 2013). Third, the Marine Corps sent requests to industry to develop a Marine Personnel Carrier (MPC). The MPC is intended to be an inland capable vehicle that could take over for the ACV once ashore. The key performance parameters require the MPC to function across the full range of military operations but be light enough for transport by modern ship-to-shore connectors (PEO LS, 2011). The fourth alternative involved upgrading the AAV to meet mission requirements long enough for the ACV and MPC to enter service between FY20 and FY22 (Feickert, 2013). Currently the Marine Corps is looking to extend the service life of the AAV long enough to allow for the ACV to be developed. Additionally, research is ongoing to determine whether or not the MPC will be necessary.

As the war in Afghanistan winds down, the nation looks to increase its presence in the Pacific Theater (Defense Strategic Guidance, 2012). The Marine Corps seeks to break away from being a "second land army" and get back to its amphibious roots (Amos, 2012). With the Marine Corps' vehicle of choice to deliver landing forces ashore in transition, decision makers require the necessary data to make sound decisions. Upgraded versions of the AAV will be faster but also heavier. What will that mean for the crew and embarked infantry of an AAV that sinks for some unforeseen reason? Does increasing the size of the suspension and the power train change the buoyancy characteristics of the AAV? If so, will it sink faster and in what manner?

A 2011 presentation by the Program Executive Office for Land Systems (PEO LS) describes the priority of the SLEP for the AAV to be survivability (PEO LS, 2011). Survivability is defined as:

> [P]rotection against fratricide, detection, and instantaneous, cumulative, and residual nuclear, biological, and chemical effects; personnel survivability against asymmetric threats; the integrity of the crew compartment; and provisions for rapid egress when the system is severely damaged or destroyed. (DoD HSI Management Plan, 2009, p. 4-5)

Unlike all other vehicles in the U.S. arsenal, the AAV is the only one required to move from ship to shore and then partner with other vehicles to continue the assault inland. Thus, survivability considerations for the AAV start when it enters the water, as opposed to when the AAV is first susceptible to enemy fire.

In order to determine the extent to which physical changes in the AAV alter its survivability, baseline performance measures must be established. One such performance baseline is how quickly embarked personnel can egress a sinking AAV in its current configuration. Collecting egress data on subjects embarked on a sinking AAV is an extremely dangerous undertaking. A less risky initial study would be to study egress on dry land. With preplanned routes and procedures, such a study should yield the data needed to begin comparisons to the ACV and in riskier waterborne scenarios.

Resurgence in amphibious training due to a greater emphasis on the Pacific Theater will lead to increased risk of waterborne incidents. Procedures for training personnel to operate safely in the water can ensure incidents like the one involving Sergeant Rice do not occur again. For example, when transporting at full capacity, an AAV contains 17 subjects instead of the two who were aboard when Sergeant Rice died. What would be the optimal escape route to ensure everybody survives? After Sergeant Rice's accident, it was learned that the crew hatches had remained open, allowing water to fill the vehicle rapidly as it went nose down, but also permitting the crewmembers to escape once the pressure

from the inflowing water had subsided (Accord, 2012). So, is it more important to keep the hatches shut or leave them open? These are just a few questions regarding AAV SOPs. In order for the Marine Corps to reclaim the ability to “storm the beaches,” it must ensure that AAV SOPs produce a safe and efficient environment in which to train.

3. Statement of Work and Test Plan

In response to inquiries made at the SE-OPT and from Program Manager Advanced Amphibious Assault (PM AAA), a SOW was drafted to answer specific questions regarding emergency egress and evacuation. The SOW differentiated between evacuation (i.e., a slow sinking or disabled vehicle) and egress (i.e., a fast sinking or submerged vehicle) scenarios. Factors for the experiment proposed in the SOW included 17 or 21 embarked infantry plus three crewman, two different personal flotation devices and multiple escape routes. Weapons and body armor would remain on the subject during evacuation but be removed during egress. The SOW included a requirement to secure a three-day supply of food and water plus the approach load for all embarked infantry in accordance with the stowage plan. The SOW directed subjects to transfer to a simulated recovery vehicle regardless of sink scenario. Several other stipulations regarding deliverables, including the test subjects’ anthropometric measurements, were requested. The SOW required Amphibious Vehicle Test Branch (AVTB) to submit a feasibility of support (FOS) request for infantry with a normal distribution between the 5th and 95th percentile of male Marines. References made to learning effects suggested randomization but were contradicted by the requirement to perform practice trials before every specified treatment. Although not specified, the SOW inferred the response variable would be the time it took for subjects to escape under various conditions. The next section will review several studies that investigated emergency evacuation from several different platforms. The studies were used to inform the design of the present research effort.

D. REVIEW OF RECENT EGRESS GUIDELINES PRACTICES AND RESEARCH

Research involving human egress from transportation systems is not extensive. The studies vary in the type of platform investigated and type of threat (e.g., fire, sinking). Further, the various studies proposed used methods ranging from computer-aided design simulation to full factorial human subject testing.

Manpower and Personal Integration (MANPRINT) is the U.S. Army's program for implementing Human Systems Integration (HSI). MANPRINT utilizes the Test Operations Procedure (TOP) 1-2-610 parts I and II: *Human Factors Engineering Procedures* and *Human Factors Engineering Data Guide for Evaluation* (HEDGE). The TOP includes various human factors design checklists. Many test plans and questionnaires that examine ingress, egress and emergency egress, describe emergency egress testing procedures as a familiarization run followed by three trials of a specific treatment (trial) recorded for time. Several test plans consider the response variable of egress time to be the time it takes a subject from the seated position to exit the vehicle by the specified route to a distance of three meters from the vehicle. This serves not only to ensure the design of the vehicle does not impede egress, but that the subjects are able to get a suitable distance away from a vehicle. Test subjects wear mission essential equipment, as required by their military occupational specialty (MOS). This approach helps determine if the personal equipment makes a subject too bulky to egress through a particular hatch or if snags occur. All hatch or route combinations are tested. Anthropometric measurements of each test subject are recorded and used to determine whether the subjects represent the 5th to the 95th percentile of the target population for that vehicle. Surveys or questionnaires administered after the test, or after each treatment of trials round out the emergency egress experimentation procedure for Army vehicles.

Aviation ingress, egress and emergency egress testing follows the guidelines set forth in the Army Test and Evaluation Command (ATEC) Test Operations Procedure (TOP) 7-3-529. The TOP stipulates many of the same

guidelines used for ground vehicles. The TOP makes a distinction between emergency egress and emergency evacuation as the difference between testing individual egress times from all seat locations and a full complement of crew and subjects egressing simultaneously. Altering visibility between daylight and restricted light serves as an additional option. Unlike the vehicle testing, the TOP cites research suggesting that post-crash fires allow the crew and subjects 7 to 16 seconds to escape. The TOP states, “For a crew to survive under these conditions, they must be able to safely egress the aircraft within 10 seconds and 30 seconds for aircraft fitted with crash-resistant fuel tanks” (ATEC, TOP 7-3-529, 1991, p. A-1).

Kennedy, Durbin, Faughn, Kozycki, and Nebel (2004) conducted an evaluation of the U.S. Army’s Comanche (RAH-66). They defined emergency egress as “actions performed by a crew member to quickly and safely leave the aircraft during emergency conditions” (Kennedy et al., 2004, p. 3). The study focused on the potential interaction between the crew station and the Air Warrior Ensemble. The mockup of the Comanche fuselage they used lacked rotor blades and employed crash pads to prevent injuries. These, along with other safety constraints, proved a necessary tradeoff to ecological validity. Anthropometry, route of ingress or egress and aircrew clothing ensemble served as the input variables, while mean emergency egress time served as the response variable. Ingress and egress times served only to provide an assessment of “movement difficulties, potential safety problems, volume-of-space issues,” etc. Therefore, no descriptive statistics were calculated (Kennedy et al., 2004).

Strict adherence to the Army’s regulations guiding ingress-egress testing made the findings suitable for comparison to new or modified aviation systems. Four subjects representing the 5th percentile for female, 50th percentile female, 50th percentile male and the 95th percentile male of the Army pilot population served as the test subjects. Extensive anthropometric measurements and multiple recordings from motion capture video equipment fed a human figure modeling system called Jack (Unigraphics Incorporated). Nonparametric analysis

of the emergency egress trials and questionnaires formed the basis of the study's results. In 48 trials, the study yielded an average emergency egress time of 16.6 seconds, with only two trials taking longer than the 30-second threshold. The 95th percentile male was the test subject involved in both instances. Jack software enabled the researchers to pinpoint the location of the test subject's body and equipment that created difficulty during ingress or egress. Questionnaire results supported the objective data. Analysis indicated that repeated trials created a training effect, in which times from the second half of trials were faster than the first half.

Havir and Kozycki (2006) assessed emergency egress for the U.S. Army Airborne Command and Control System (A2C2S). The A2C2S is a specific work suite installed in a (UH)-60L Blackhawk helicopter. Similar to Kennedy et al. (2004), anthropometry and aircrew clothing ensemble served as the input variables, while emergency egress times served as the response variable. Blockage of egress routes was another multi-level input variable introduced by the researchers. Anthropometric measurements and motion capture video were collected and fed into the Jack software. The A2C2S study focused on individual crewmember's emergency egress procedures rather than the entire five-member crew as a whole. Analysis included descriptive statistics of the egress trials and questionnaire responses.

The first emergency egress trials had no blocked exits and averaged 8.5 seconds. The second set of trials involved blocking exits on one side to simulate the aircraft on its side and averaged 19.3 seconds. Survey analysis on a 5-point Likert rating scale rated the egress moderately easy in both scenarios. The final phase of testing varied the exits blocked and had the test subjects egress through different routes. The results ranged from 13.5 to 29 seconds. In one instance, the large male subject became stuck and the trial had to be repeated. The researchers created a model using Jack software to make work station design changes that would lower egress time.

Ryack, Smith, Chamlin and Noddin (1976) designed an experiment to test egress from a submerged helicopter. The researchers used an H-3 helicopter fuselage attached to a crane. The crane lowered the fuselage into the water at which time the fuselage would invert. Trained Navy divers served as test subjects. The experiment examined egress route, illumination (daylight or restricted) and emergency hatch lighting (light or no light). The response variables were time to release of seat belt, time to activation of the hatch, and time of arrival to the surface. Test subject seat assignments were randomized. Illumination and route trials were blocked and repeated. An emergency breathing apparatus was made available to each subject.

An Analysis of Variance (ANOVA) revealed statistically significant effects and interactions. The factors of window (route) and illumination were found to be statistically significant, while the factor of daylight versus restricted was not. Egress times ranged from 5.22 to 11.45 seconds. The study concluded that window illumination affected egress times and would have had a greater effect on untrained (non-divers) subjects.

Griffin and Mullis (2007) authored an interim test report for the system development and demonstration (SDD) phase of the EFV. The report encompassed engineering tests directed at multiple performance parameters of the EFV prototypes. A section of the report involved a comparative analysis of ingress and egress from several different armored vehicles (including the AAV) with the EFV prototypes. U.S. Marines and U.S. Navy Corpsman served as test subjects. Prior to testing, recording of anthropometric measurements ensured a representative sample between the 5th and 95th percentile of male Marines. Part of the experiment focused on the waterborne emergency egress of subjects from the seated position to the top of the vehicles. Vehicles sat atop dry, flat land and the response variable of Egress Time began at notification and ended once the final subject reached the top of the vehicle. Input variables consisted of visibility (daylight or restricted), load plan variation (four locations of stowing packs), squad mission equipment variation (six different troop configurations varying

weapons and amount of subjects between 14 and 20), Mission Oriented Protective Posture (MOPP) level (MOPP levels describe layers of gear military members use to protect themselves during a chemical or biological attack. In this experiment, only MOPP-0 and MOPP-IV were used) and route (forward and all top hatches). A practice run preceded each version of the timed trial to familiarize the subjects. As the test progressed, Subjects opted out of repeating the practice run prior to each trial. Each timed trial consisted of three repetitions conducted sequentially without randomization. Although the AAV served as a control for the EFV egress experiment, no data involving Egress Times from the AAV did not occur was kept for record.

McLean, George, Chittum and Funkhouser (1995) completed a series of experiments designed to simulate emergency egress from Type III over-wing exits on transport airplanes. The Type-III exit is a small (20″ x 30″) opening much like the egress port in an AAV. The purpose of these experiments was to determine the most effective passageway from the center aisle to the exit. Seat placement and seat encroachment distance into the exit opening were the input variables. Egress time for the group, as well as each individual, served as the response variables.

McLean et al. (1995) employed several methods to achieve the most realistic egress times possible. First, two groups with similar weight and height but different ages (20–40, 40–60) were chosen as test subjects. Age differences were used to evaluate agility effects. Second, the groups were familiarized with emergency egress procedures, including the opportunity to egress through the Type-III exit in the absence of a seat assembly. Third, passageway configuration was counterbalanced to reduce carryover effects of prior experience. Common carryover effects include learning, fatigue, catching on, assimilation and contrast (Price, 2005).

McLean et al. (1995) also randomized between the groups based on passageway and seat factors. This meant that the order of passageway widths and seat encroachments Group 1 conducted differed from Group 2 in an attempt

to see if test subject naiveté and learning effects confounded the response variable. Additionally, they randomized individual seating assignments within the groups to give each subject a new starting position for each trial. Further, a monetary incentive to encourage highly motivated egress was awarded to the three fastest subjects in each group across all egress trials. However, the rules stated subjects could not jump in front of others, so the incentive drove a "competitive cooperation" in which it was in the best interest of the subjects to help those in front of them. A three-way ANOVA was used to analyze the main effects and possible interactions of the experiment. The results showed significant effects of age, passageway width and seat encroachment distance with no significant interactions. Age-related differences in agility were indeed a major factor in using the Type-III exit evacuation system. Passageway configuration also affected egress times.

The findings of the McLean et al. (1995) study received criticism from airlines and airplane manufacturers because the experimental design lacked "absolute fidelity when experimentally simulating an emergency evacuation, in all its potential manifestations" (McLean, 2001, p. 1). Specifically, the experiment was simple in nature and subjects were allowed to "practice" egress beforehand.

In response, McLean authored *Access-to-Egress: A Meta-Analysis of the Factors That Control Emergency Evacuation Through the Transport Airplane Type-III Overwing Exit* (2001). McLean referenced Perrow's *Normal Accidents* (1999) extensively.

Citing Perrow's assertions, McLean concluded that the criticisms of the 1995 Type-III study were misguided by stating, "The problem with such an ideological approach is that it is built on belief and assumption, not data, confounding science and technology with undefined contingencies and constraints" (McLean, 2001, p. 5). McLean went on to analyze the results and observations for all Type-III exits and concluded that:

> Interactions among these subsystems and elements, where found, have been shown to be generally linear, once again being more

> related to the degree to which human factors effects are evidenced…Thus, if physical subsystem elements provide inappropriate egress workspace, modify them; if information subsystem elements are not informative and useful, perfect them; and if the operator/user subsystem elements are not effective or efficient, instruct them. Only through this type of balanced approach will the success of the [system] be better guaranteed. (McLean, 2001, p. 31)

Mclean et al. (2002) organized another experiment to readdress the effects of passageway configuration and human factors on egress through the Type-III exit and replicate the 1995 experiment. The additional factors added to the design allowed for more potential interactions and therefore more analysis. The researchers conducted egress trials with 48 groups whose members varied in size and age. The larger number of groups permitted counterbalancing. The study employed a between-subjects design to ensure naiveté for each individual and condition and then used three extra trials for each subject test for interactions. In all, 2500 subjects participated in four trials each for a total of 10,000 individual egress events through the Type-III exit.

McLean and Corbett (2004) issued a final report based on the 2002 study in which they concluded:

> The findings replicate prior research showing that the physical attributes of subjects produce large differences in emergency evacuation performance, whereas airplane configuration has minimal effects on emergency egress, as long as ergonomic minimums are respected. Where such problems do exist, evacuation experience acts to mitigate such negative effects, as does proper subject management by flight attendants. (McLean et al., 2004, p. i)

To conduct an emergency egress experiment on a given system, a clear definition of the objective is needed. If the system is a prototype, a design test will expose flaws where humans interact with the system, although it may not clarify the type of design changes needed. If the system is already well established (i.e., a 42-year-old AAV), then how humans perform in that system is likely to be the primary focus. Although the military is interested in the technical

aspects of a system and the manner in which humans interact with the system, the acquisition process is composed mostly of engineers, who understand the former better than the latter. Fortunately, the AAV Egress study described in the AVTB Test Plan established the requirement to understand the HSI aspects of egress from a sinking AAV.

The egress research described above provides some scenarios, methods and objectives that are similar to the present AAV study but others that are different. The AAV, like aircraft that possess Type-III overwing exits, is a well-established system beyond the developmental or operational test and evaluation (OT&E) phases of system acquisition. The existence of crew to assist subjects is another similarity. Other similarities are that subject space is a single compartment and the imminent danger to the subjects requires emergency to egress from that space.

The AAV Egress Study examines at the scenario of a sinking AAV. In contrast, the Access-to-Egress research studied a burning plane fuselage. The AAV has multiple hatches with different dimensions from which subjects can egress, while the fuselage has one exit with multiple possible passageway dimensions and seat encroachments. The AAV Egress Study was undertaken to test a specific population, while the Access-to-Egress studies used a limited cross-section of the general population. (People of all ages can fly on commercial airlines, but the experiment did not include the very young or old for safety reasons.) The present study leveraged the strengths of previous egress studies while attempting to avoid their shortcomings. The AAV Egress Study utilized a full-factorial, within-subject design, with counterbalancing to reduce carryover effects. Similar to previous studies, egress time is used as the response variable and an ANOVA was used to determine main effects, and any interactions.

1. Hypotheses

The research questions posed in the introduction guided the methods and analysis used in the AAV Egress Study. The factors chosen for the experiment

were illumination, number of subjects, body armor, personal flotation device (PFD), weapon posture and route. The response variables included Egress Time, Transfer Time and Load Time. Explanation of the input variables and the response variables appear in Chapter III.

2. Research Question One

The first research question asks, “What factors provide Marines in a sinking AAV the best chance for survival?” Dividing the question into parts allowed for a more thorough investigation. The following paragraphs provide hypotheses for each factor.

The null hypothesis for the Illumination factor states that there is no significant difference in the time it takes for subjects to egress from an AAV during daylight or restricted conditions. The alternative hypothesis states there is a significant difference; daylight will result in lower times.

The null hypothesis for the Subject factor states that there is no significant difference in time it takes for 17 or 21 embarked infantry to egress from the AAV. The alternative hypothesis states there is a difference; 17 subjects will egress faster than 21 subjects.

The body armor factor was combined with the personal flotation device (PDF) factor to create three levels. See Chapter III for a more detailed explanation. The null hypothesis for the combined Armor||PFD factor that there is no significant difference in time for subjects required if they (1) drop their body armor while wearing the LPU-32; (2) keep their body armor while wearing the LPU-32; or (3) keep their body armor while wearing the HESP. The alternative hypothesis states at least one combined factor is different from the others.

The weapons posture factor was combined with the route factor to create six levels. See Chapter III for a more detailed explanation. The null hypothesis is that there is no significant difference in egress times for subjects who leave their weapon while exiting through Routes 1, 3 or 4 and those who take their weapon

while exiting through Routes 2, 3, or 5. The alternative hypothesis states at least one combined factor is different from the others.

3. Research Question Two

The second research question asks, “Is the design of experiment appropriate given the safety constraints?” The answer requires subjective interpretation of the SOW, SOP and all data collected.

The Assault Amphibian School Battalion Order P3000.1H is the most recent version of the common SOP and describes evacuation and egress procedures (BNO P3000.1H, 2012, Appendix J). The SOP states a sinking AAV has had its “watertight integrity compromised to the extent that water entering the vehicle exceeds the amount of water being pumped out” (BNO P3000.1H, 2012, p. 3–6). At the point in which the crew chief realizes the AAV is taking on water and the vehicle’s bilge pumps are not matching the water entering the vehicle, he must make determination decision to evacuate the vehicle. The SOP describes procedures for both slowly and rapidly sinking scenarios. This study examines sinking with the combination of the route and weapons posture factors. Some combinations of factors are associated with the SOP for slowly sinking scenarios whereas the others are aligned with rapidly sinking scenarios.

4. Research Question Three

The third research question asks, “Does the current SOP establish the conditions that will optimize survivability of the subjects and their equipment during waterborne operations?” The data, observations and survey responses will provide insight as to the effectiveness of the elements listed in the SOP.

III. METHODOLOGY

A. OVERVIEW

PM AAA tasked AVTB to perform testing in accordance with the SOW. AVTB generated a test plan and submitted it to PM AAA. The test plan mirrored the SOW with minor exceptions concerning factors and response variables. The test plan specified escape routes for each sink scenario excluding the turret hatch. Additionally, the test plan provided a run matrix and questionnaire.

The overall objective of the experiment was to determine the time a reinforced rifle squad requires to egress from an AAV under optimal conditions. The assumption is that if the egress time is less than the simulated time for an AAV to sink in the water, a favorable survivability situation exists. Altering the characteristics of the AAV could alter the simulated time for the AAV to sink. If the egress time remains less than the simulated time, then the survivability is still favorable. Decisions were made by the PM to sacrifice realism for the sake of safety. For example, rather than conducting the experiment in water with a sinking AAV, the vehicle was located on dry land.

The data are analyzed with a linear model, consisting of four independent variables and one primary response variables. These independent variables were designated by the sponsors and experimenters. The final design was a 2 x 2 x 3 x 6 full factorial design. The primary response variable is Egress Time: time to egress to the top of the AAV. Variables related to Egress Time that also were recorded are: Transfer Time: time to transfer from the top of the disabled AAV to the recovery AAV and Load Time: time to load subjects.

The Design of Experiments (DOE) methodology provided an organized approach to data collection intended to maximize the range of possible Egress Times with a set number of trials. Several SOP considerations eliminated unnecessary treatments, creating a full factorial (2 x 2 x 3 x 6) design with 72 trials. Each treatment was replicated three times giving a total of 216 trials.

The experiment used a group of Marines from AVTB and Company B, 1st Battalion 4th Marine Regiment (B/1/4). Each member in the group provided demographic and anthropometric data that might be relevant to Egress Times (see Chapter IV).

B. RESEARCH TEAM

The experiment took place at Camp Pendleton's Del Mar boat basin from 6 to17 August 2012. AVTB team consisted of one civilian test engineer, one Marine Gunnery Sergeant (AAV MOS), four civilian laboratory technicians and five Marine AAV crewmen. The Naval Postgraduate School's (NPS) team included two HSI professors, one postdoctoral research associate, one Marine officer graduate student and two undergraduate students. Company B, 1st Battalion 4th Marine Regiment (B/1/4), provided the 25 infantry, who served as test subjects.

C. RESEARCH SUBJECTS

The AAV is the Marine Corps' primary ship-to-shore connector for opposed landings in amphibious assaults. Amphibious assaults are one of the primary missions of the infantry. The Marine Corps' infantry and AAV crewmen military occupational specialties (MOS) are open only to males. Rigorous physical tests ensure males with these MOSs can perform the mission essential tasks required by the AAV Training and Readiness (T&R) Manual. Further, all Marines involved in waterborne operations must meet additional water survival requirements. These physical requirements narrowed the target population down to subjects serving in infantry battalions.

D. EQUIPMENT

The AVTB staff and laboratory technicians set up a large test bay to perform the experiment. Tape and cardboard on the test bay windows prevented light from entering during simulated restricted trials, allowing for experimentation during the day with no illumination. AVTB provided one AAV with current

specifications to serve as the notional sinking AAV. Another AAV, parked alongside, was used as the recovery vehicle for the subjects to transfer to after they egressed from the notional AAV. A staircase allowed the subjects to climb down from the recovery AAV after the transfer. Closed circuit digital cameras captured video and audio data of each run from inside the troop compartment and outside the AAV. All video and audio data files were time stamped.

The NPS team brought items from the HSI Laboratory to augment the experiment at AVTB (see Appendix E for list). Among these items were the anthropometry equipment used to measure each Marine participating in the experiment.

E. VARIABLES

The Variables Section describes in detail, the dependent and independent variables used throughout the experiment and analysis.

1. Response Variable

The main response variable (Egress Time) was time elapsed from notification to egress of the last subject reaching the top of the AAV.

2. Snag Variable

At the end of each trial each subject was asked if he had become snagged or stuck during the egress or evacuation. The subject number and the manner in which he was snagged were recorded.

3. Independent Variables

The SOW generated at the SE-OPT specified multiple factors and levels based on SOP, safety considerations and desired treatments for the two egress scenarios. The following are the factors and levels used in the study.

a. Illumination (Daylight or Restricted)

During daylight trials, the cargo bay doors were open allowing for ample illumination. During restricted trials, the cargo bay doors remained closed and the windows were blacked-out. The recovery vehicle used its floodlight and chem lights were placed in positions that facilitated safe movement.

b. Subject Load (17 infantry + 3 crewman or 21 infantry + 3 crewman)

A doctrinal Marine infantry rifle squad has 13 members. It is often the practice to attach or reinforce a standard rifle squad with a section from one of the squads in the weapons platoon. The resulting number of Marines in the squad is usually 17 or 21. All subjects in the trials with 17 Marines participated in the trials with 21. Additionally, the same three crewmen participated in every trial of the experiment. With minor exceptions, the subjects remained the same for all trials.

c. Body Armor and Personal Flotation Device (Keep LPU-32; Drop LPU-32; Keep HESP)

The independent variable, Armor/PDF, has three levels that capture the combination of Armor and PDF worn by subjects. The LPU-32 is the current PFD used by the AAV community. It is worn under the body armor. The LPU-41 Helicopter Egress System for Passengers (HESP) is a newer PFD and is worn over the body armor. Removing the body armor allows subjects to reduce weight and bulk. Keeping the body armor on allows subjects to begin egress procedures more quickly. Since the HESP is worn over the body armor, a condition in which subjects wore the HESP and removed their body armor was not tested.

d. Weapon and Route (Take1; Take3; Take4; Leave2; Leave3; Leave5)

The six levels in this independent variable were driven by current AAV standard operating procedure. The levels are a combination of take or leave weapon and the number of hatches used for egress: 1, 3, or 4 when weapons are taken; 2, 3, or 5 when weapons are left. In a disabled or slow sink scenario, Marines take their weapons with them when they transfer to the recovery vehicle. In a rapid sink scenario, subjects exit the AAV as quickly as possible and leave all equipment behind, including their weapons. The routes (or number of hatches) used in this study also were based on the AAV SOP. There are five hatches on an AAV: two cargo hatches; the troop commander's hatch; the driver's hatch; and the crew chief's hatch (see Figure 2). When a vehicle is rapidly sinking all available hatches are used. Sometimes, due to the condition of the sinking vehicle, certain hatches may become too hard to access or open. Therefore, rapid sink scenarios used all five hatches, only the front three hatches (troop commander's, driver's and crew chief's), or only the two cargo hatches. For a slow sink scenario, the SOP instructs subjects to leave the portside cargo hatch shut in order to stage equipment and personnel for transfer to the recovery vehicle. As a result, the slow sink scenarios used the front three hatches and the starboard cargo hatch, only the front three hatches, or only the starboard cargo hatch.

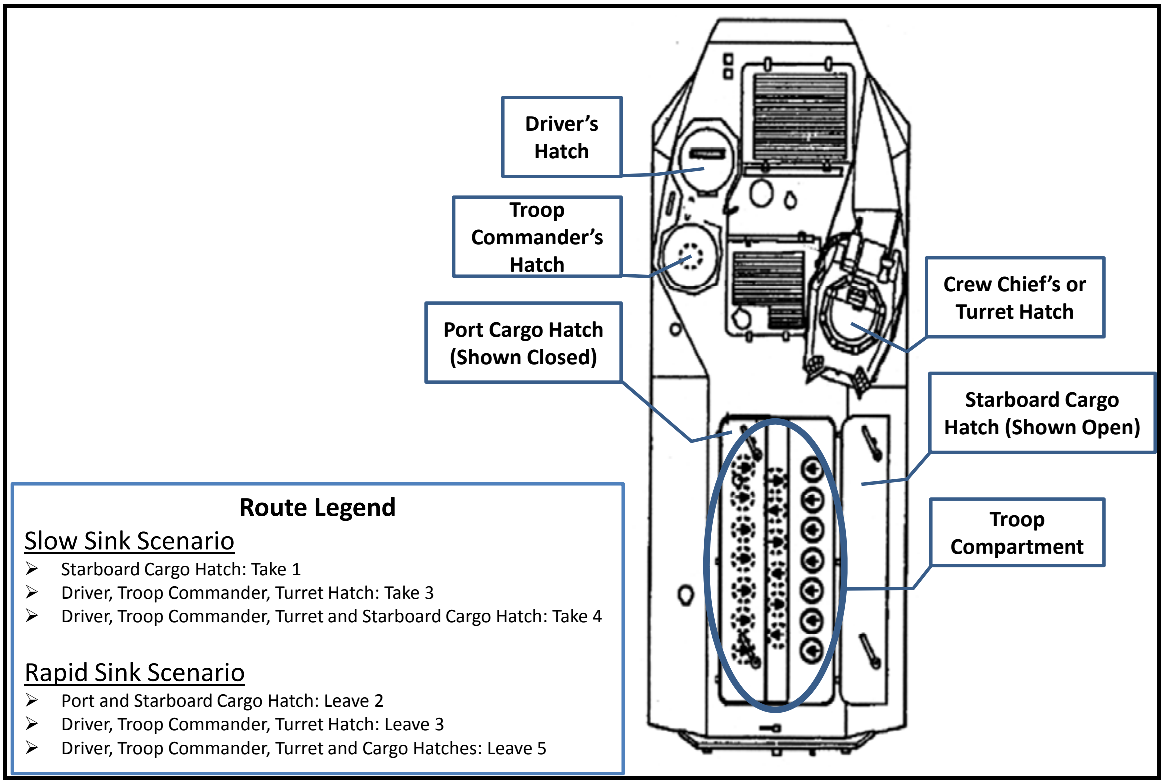

Figure 2. Top down view of AAV with hatch descriptions

F. DATA COLLECTION/PROCEDURES

The SE-OPT designated two weeks to conduct the study at Camp Pendleton, Ca. A feasibility of support (FOS) was sent to 1st Marine Division to request 22 infantry to serve as subjects (21 subjects and one alternate). Three crew members (driver, crewman, crew chief) would participate throughout the experiment as well. Subjects were told participation was completely voluntary. They were briefed on the study and then they all read and signed informed consent statements. Next, the research team measured the body dimensions of all subjects. There were eight anthropometric measurements of interest. They were stature, weight, chest depth, shoulder circumference, chest circumference, waist circumference, buttock circumference and shoulder breadth. Since subjects traveling in an AAV will always be wearing a uniform and equipment, measurements were taken in their shorts and t-shirt (PT gear), in their uniform (Slick) and finally with their combat load (see Appendix D for measurements).

Next, the subjects performed three familiarization trials in which they loaded into the AAV, were told which hatches to use, and whether to take their weapons and wear their body armor. Load times and egress times were recorded so the research team could validate the data collection plan for the remainder of the study. Each evening, data from that day's trials were entered into Microsoft Excel spreadsheets. Each Marine was assigned a subject number, a specific weapon, and a seat assignment and these remained constant throughout the study.

During all trials the researchers positioned themselves around the AAVs according to their designated task. One researcher sat on top of the "sinking" AAV with a stopwatch to record the time when the last Marine was standing on top of the vehicle. The researcher also noted when subjects became snagged. Prior to each trial a Marine GySgt gave final instructions to the subjects and the crew chief. On the recovery AAV two other researchers recorded the order in which the subjects exited the "sinking" AAV. A crewman from the recovery AAV assisted the subjects in moving from the "sinking" AAV to the recovery AAV. Another researcher stood at the bottom of the staircase to ask whether they became snagged and if so, how it happened. Test engineers monitored the closed-circuit video feeds in a separate room and recorded times based on clock time. The third HSI professor sat in an elevated position observing the overall event unfold (see Appendix F for the list of the 216 trials conducted during days Two through Nine).

On the final day, the researchers administered a survey and conducted after action review with all subjects. Throughout the two weeks, members of AVTB, PM AAA and the AAV School at Del Mar provided additional assistance. Chapter IV provides the results of the data analysis.

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IV. DATA ANALYSIS

A. OVERVIEW

In this chapter, we present the analysis of the results from the experiment conducted during the AAV Egress Study. The chapter has six sections. A demographics and anthropometrics section further describes the sample of subjects used in this study. The next section discusses the response variables and factors chosen for the experiment followed by the analysis of these variables. Analysis of the number of snags gives brief insight into the occurrence of snags as the experiment unfolded. Finally, we use survey analysis to describe post-experiment surveys gathered from each subject.

B. DEMOGRAPHICS

In this section, we explore the demographics of the test subjects. Figure 3 shows the distribution of age for the sample. The median age is 20, the mean is 20.65 and the standard deviation is 2.48. The range of ages is from 18 to 27.

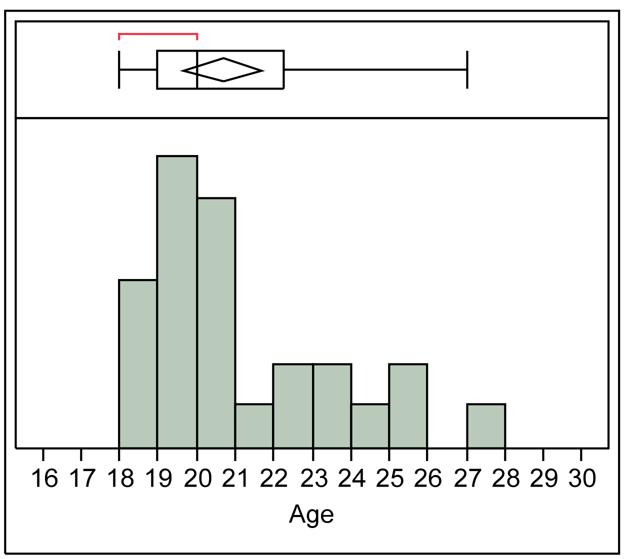

Figure 3. Distribution of Subject Age in years

The majority of the subjects were new to the Marine Corps. Time in service (TIS) is each subject's service time measured in months. Figure 4 shows the distribution of TIS. The median service time is 7.5 months the mean is 17.9 months and the standard deviation is 21.75 months. The crewman had the longest service time followed by the Marine who acted as the troop commander and sat in the designated troop commander seat. The range of TIS is from 5 months to 79 months.

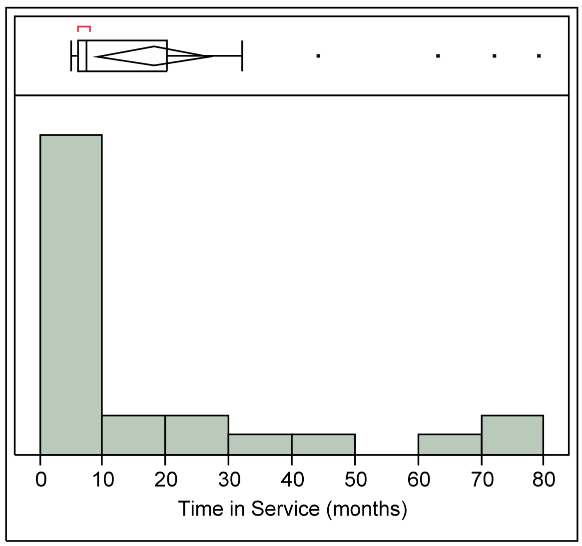

Figure 4. Distribution of Subject TIS in months

To illustrate the level of experience beyond TIS Table 1 shows the number of subjects with zero, one or two deployments.

Table 1. Deployment Distribution

Deployments Summary			
Deployments	**None**	**One**	**Two**
Subjects (26)	18	4	4

Another indication of experience is individual rank. Table 2 shows the distribution of rank for the sample. The crewmen were the only noncommissioned officers (E4 and E5) in the sample. The other 23 subjects were Lance Corporal and below (E3 and below).

Table 2. Distribution of Rank: Private (PVT);Private First Class (PFC); Lance Corporal (LCPL); Corporal (CPL); Sergeant (SGT)

Rank Summary					
Rank	PVT (E1)	PFC (E2)	LCPL (E3)	CPL (E4)	SGT (E5)
Subjects (26)	1	19	3	1	2

To assess the subjects' conditioning level, physical fitness test (PFT) and combat fitness test (CFT) scores provided insight. Figure 5 and Figure 6 show the distributions of subject's most recent PFT and CFT scores, respectively. Table 3 shows the range of each score (it is important to note that a perfect score is 300 for either test).

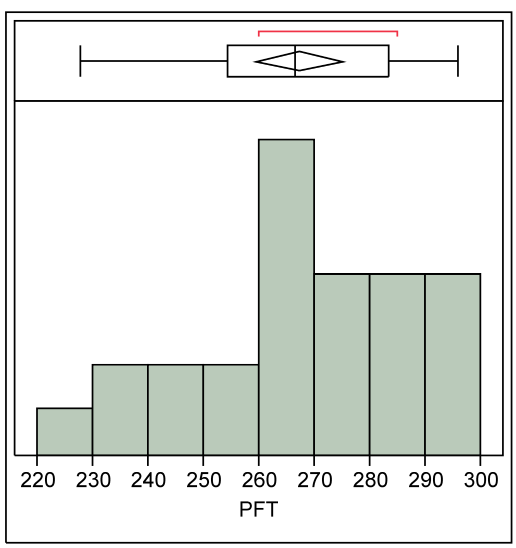

Figure 5. Distribution of PFT Scores

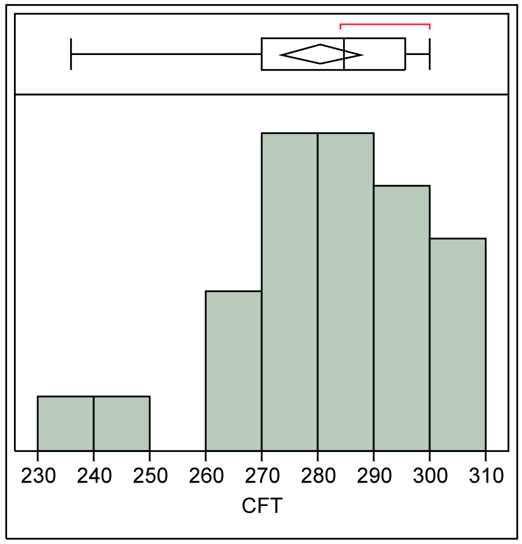

Figure 6. Distribution of CFT Scores

Table 3. Summary Statistics for Physical Tests

Physical Condition Summary		
Statistic	PFT	CFT
Median	266.50	284.50
Mean	267.10	280.40
SD	19.49	17.55
Minimum	228.00	236.00
Maximum	296.00	300.00
N	26	26

The demographic data revealed no relationships between physical conditioning and age or experience. Attempts to do regression analysis between the dependent variables of PFT or CFT scores and the independent variables of Age, TIS, and Deployments yielded no evidence of a relationship.

Absence of population data made comparison of the sample to the population infeasible. It appears, though, that the subjects had slightly below average age, TIS and rank, with slightly above average physical conditioning.

With the absence of infantry noncommissioned officers, the group of subjects appeared young and inexperienced. Further, they had an average of 267 and 280 for the PFT and CFT, respectively. The high physical test scores indicate above average physical condition. For reference, an average reinforced rifle squad contains four to five noncommissioned officers with one or two staff noncommissioned officers (E6 and above) and, quite often, a company grade officer (O1 to O3). Despite the discrepancies of the demographics, the group developed a cohesive behavior as the experiment progressed. Subjects understood individual roles regarding billet and acted upon those distinctions as if they were higher ranks. Thus, although the sample did not match the population demographically, it generally resembled the population.

C. ANTHROPOMETRICS

The population for this experiment consists of infantry that are members of companies designated to operate with AAV platoons during Marine Expeditionary Unit (MEU) deployments. Unfortunately, anthropometric measurements for infantry are incomplete. Instead, for comparison, we used 138 anthropometric measurements based on a sample of 1356 males taken from the general Marine Corps population in 2011.

1. Unequipped Measurements

We first compare eight anthropometric measurements taken while subjects were in their PT gear with comparable measurements taken from the 2011 Marine Corps sample. The eight measurements are: stature (height), weight, shoulder circumference, chest circumference, waist circumference, buttock circumference, chest depth, and bideltoid breadth. All measurements are in centimeters with the exception of weight, measured in kilograms. Figure 7 through Figure 14 show boxplots comparing the Egress Study subjects to the Marine Corps sample for each of the eight measurements, respectively. The corresponding summary statistics are found in Table 4 through Table 11.

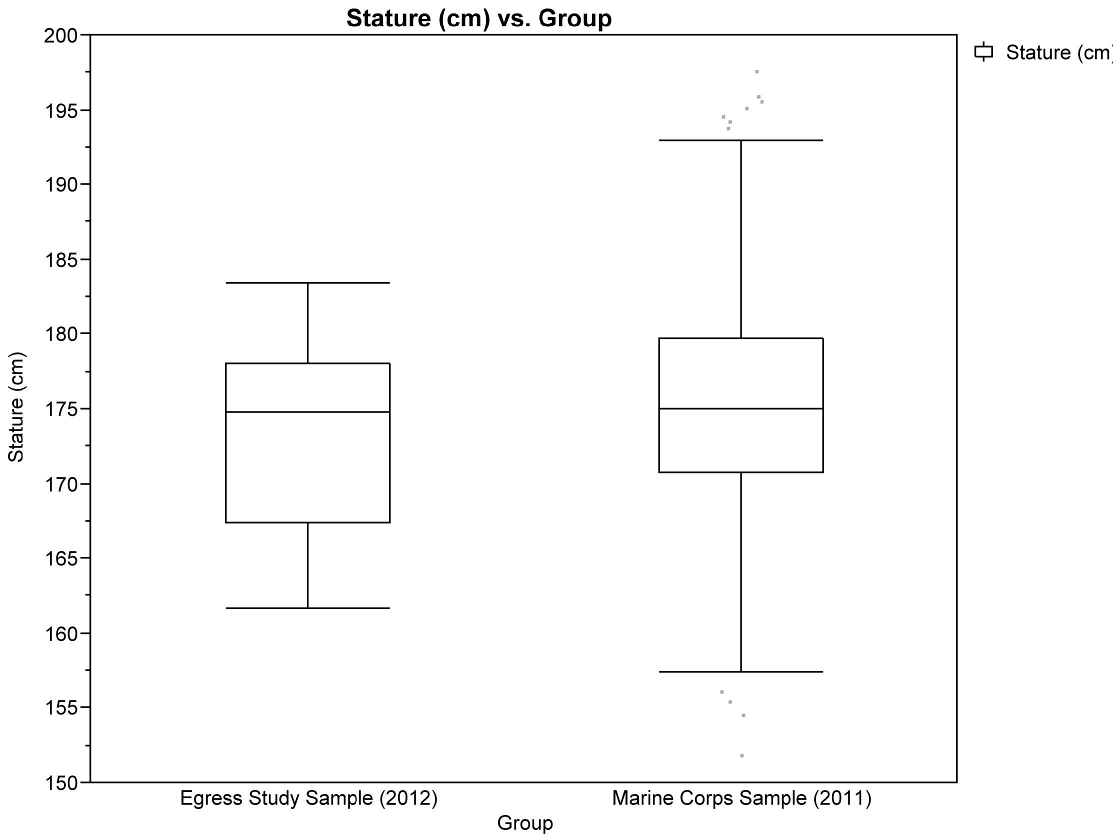

Figure 7. Boxplots of Stature for each Group

Table 4. Stature Summary Statistics

Stature Summary		
Statistic	**Egress Study**	**Marine Corps**
Median	174.80	175.00
Mean	173.40	175.30
SD	6.54	6.96
Minimum	161.60	151.80
Maximum	183.40	197.50
N	26	1309

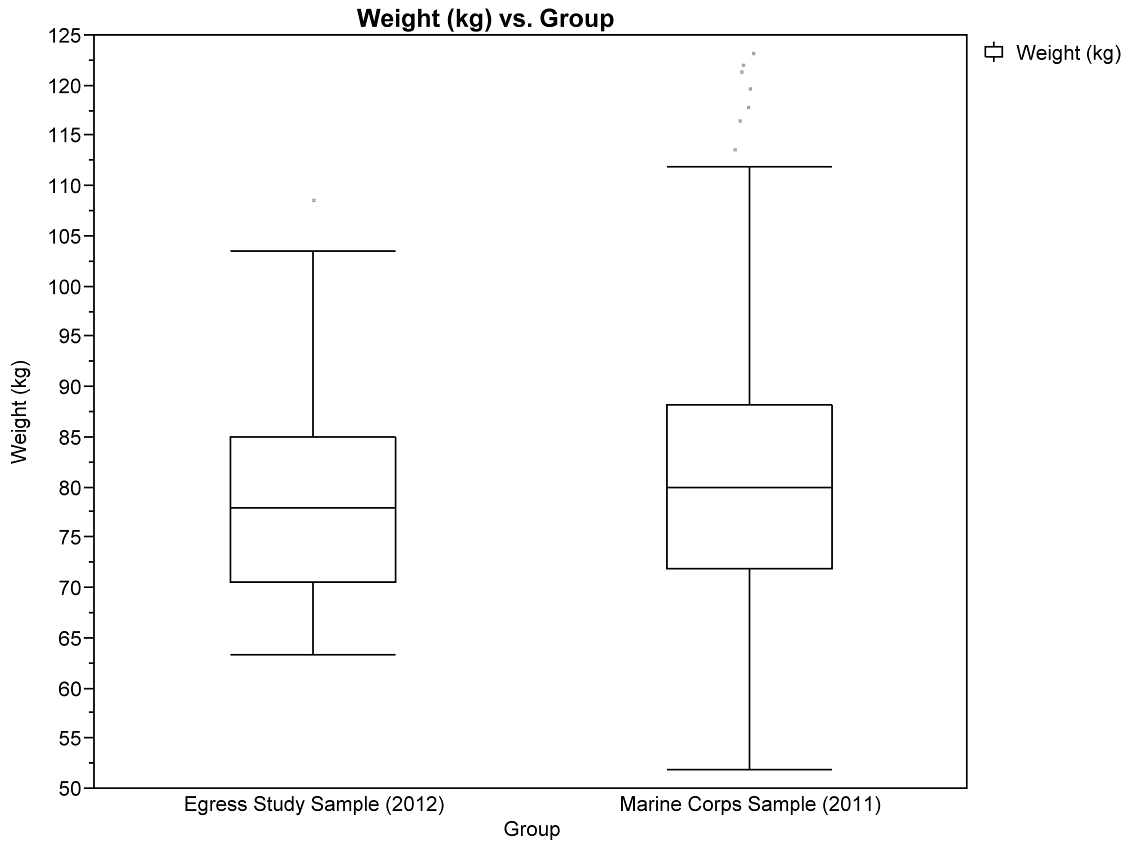

Figure 8. Boxplots of Weight for each Group

Table 5. Weight Summary Statistics

Weight Summary		
Statistic	**Egress Study**	**Marine Corps**
Median	78.00	79.90
Mean	79.00	80.60
SD	11.03	11.86
Minimum	63.30	55.50
Maximum	108.60	123.10
N	26	1305

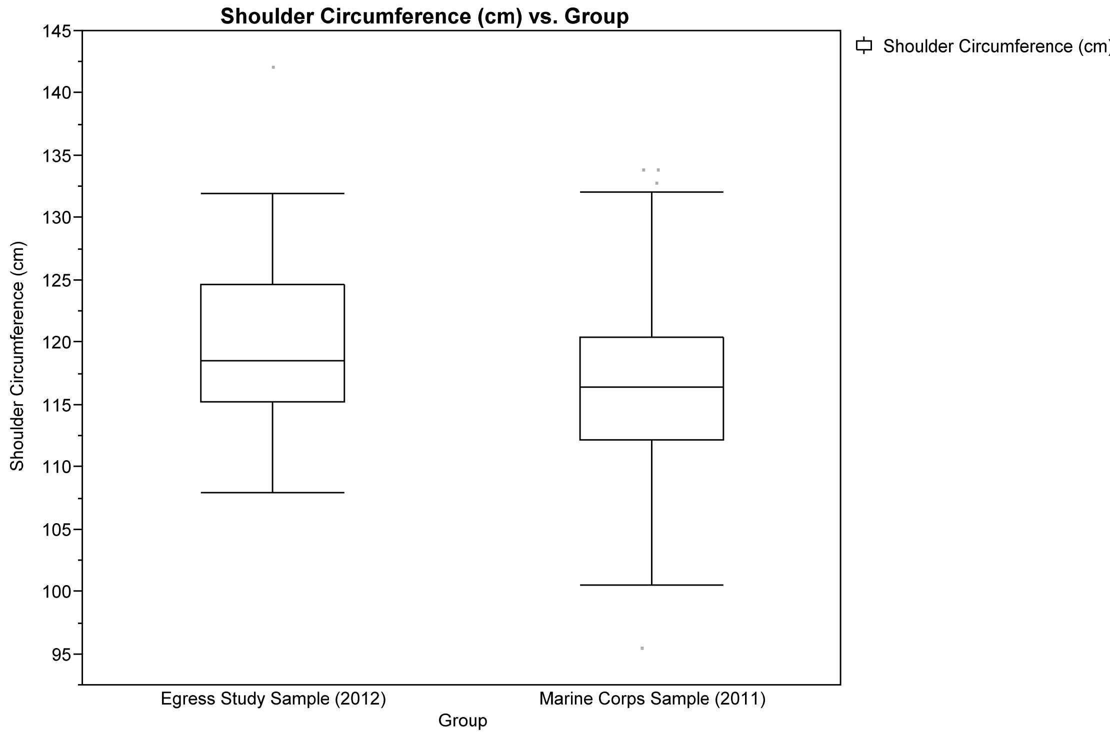

Figure 9. Boxplots of Shoulder Circumference per group

Table 6. Shoulder Circumference Summary Statistics

Shoulder Circumference Summary			
Statistic	**Egress Study**	**Egress Study (w/o subjects 6 & 20)**	**Marine Corps**
Median	118.50	117.70	116.40
Mean	120.00	118.60	116.30
SD	7.48	5.59	5.89
Minimum	107.90	107.90	95.50
Maximum	142.10	126.30	133.80
N	26	24	1305

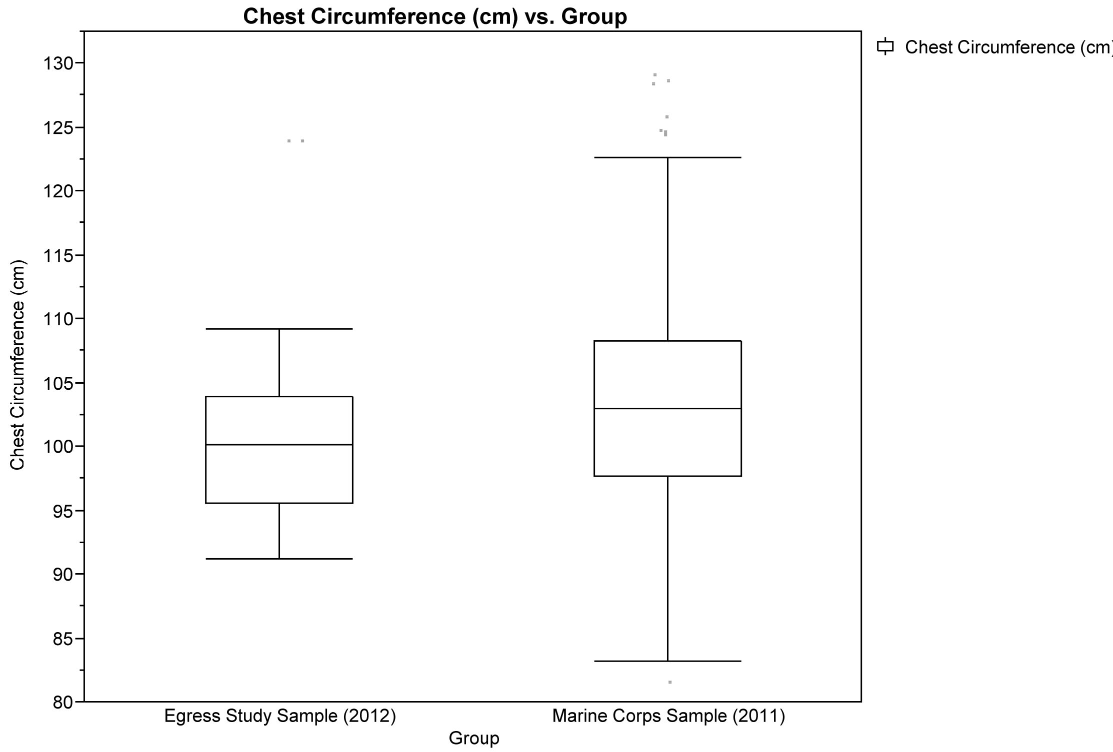

Figure 10. Boxplots for Chest Circumference per group

Table 7. Chest Circumference Summary Statistics

Chest Circumference Summary		
Statistic	**Egress Study**	**Marine Corps**
Median	100.10	102.90
Mean	101.30	103.00
SD	8.13	7.58
Minimum	91.20	81.50
Maximum	124.00	129.10
N	26	1305

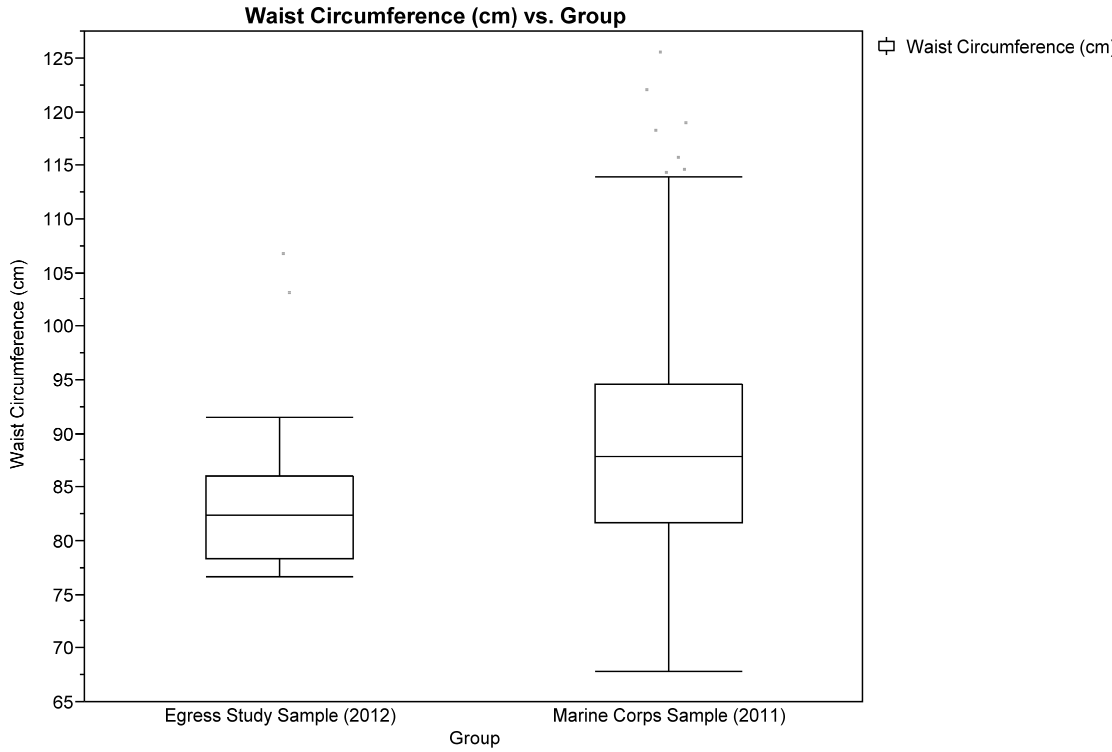

Figure 11. Boxplots of Waist Circumference per group

Table 8. Waist Circumference Summary Statistics

Waist Circumference Summary		
Statistic	**Egress Study**	**Marine Corps**
Median	82.35	87.80
Mean	83.85	88.40
SD	7.49	8.89
Minimum	76.70	67.80
Maximum	106.70	125.50
N	26	1305

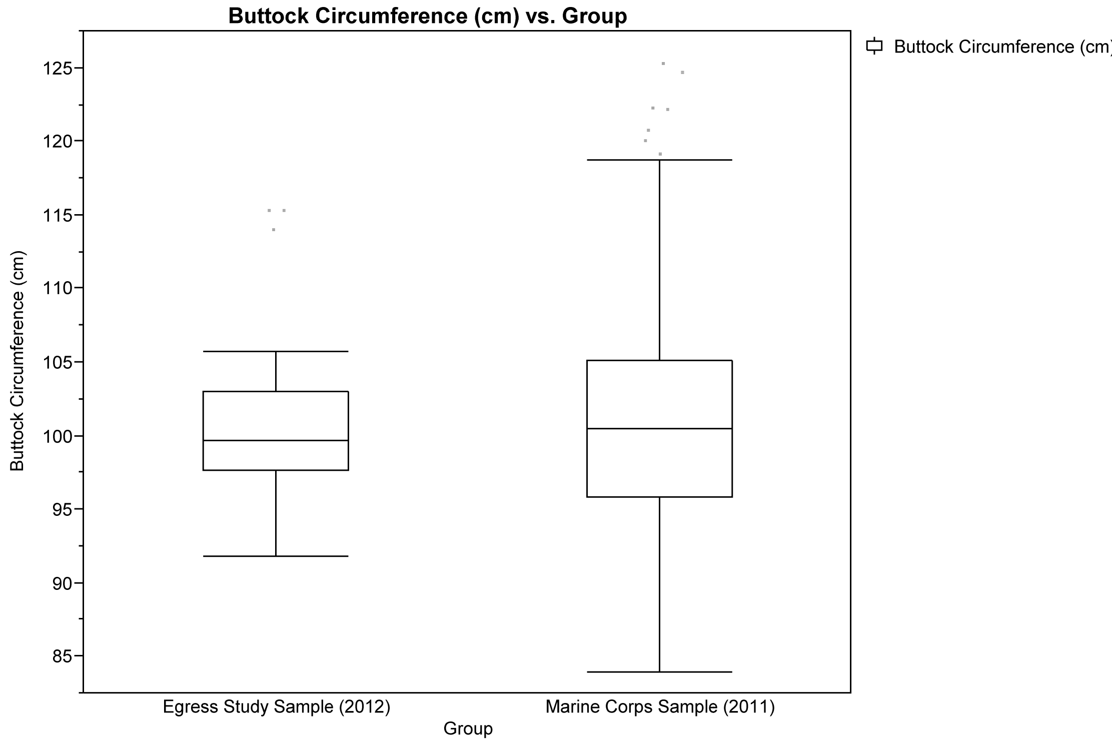

Figure 12. Boxplots for Buttock Circumference per group

Table 9. Buttock Circumference Summary Statistics

Buttock Circumference Summary		
Statistic	**Egress Study**	**Marine Corps**
Median	99.70	100.50
Mean	101.20	100.60
SD	1.18	6.76
Minimum	91.75	83.90
Maximum	115.25	125.30
N	26	1305

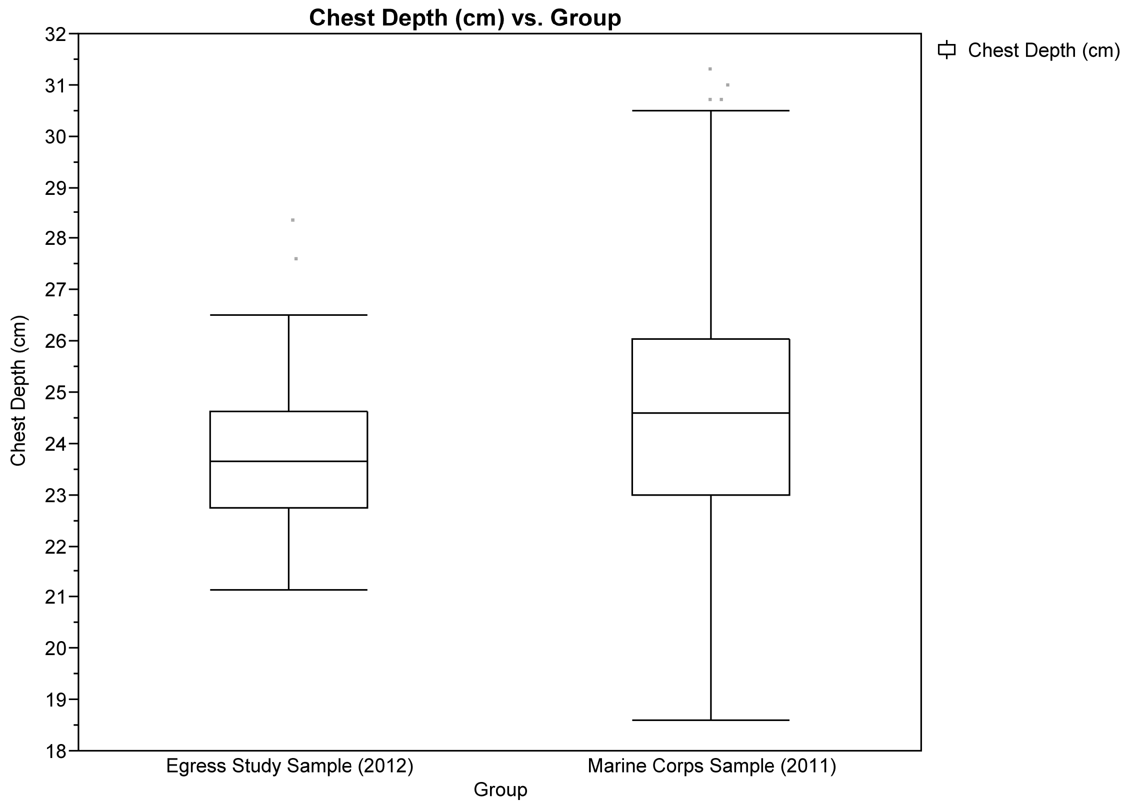

Figure 13. Boxplots for Chest Depth per group

Table 10. Chest Depth Summary Statistics

Chest Depth Summary		
Statistic	**Egress Study**	**Marine Corps**
Median	23.65	24.60
Mean	23.84	24.50
SD	1.76	2.19
Minimum	21.15	18.60
Maximum	28.35	31.30
N	26	1305

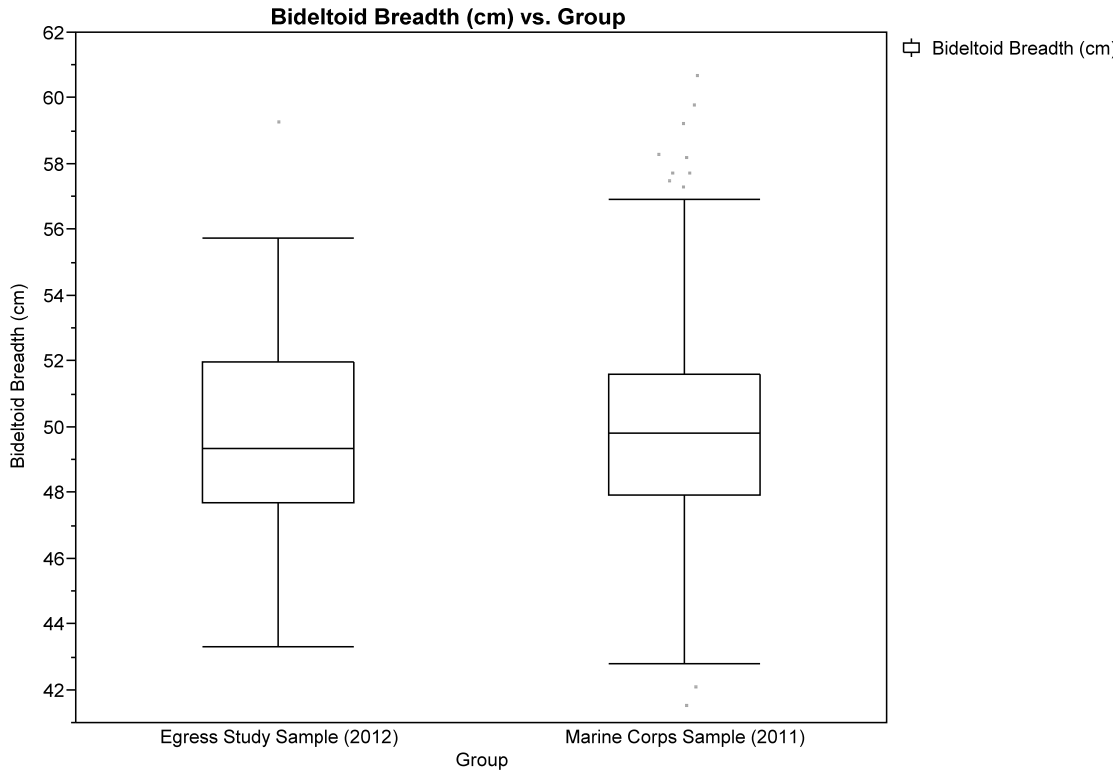

Figure 14. Boxplots for Bideltoid Breadth per group

Table 11. Bideltoid Breadth Summary Statistics

Bideltoid Breadth Summary		
Statistic	**Egress Study**	**Marine Corps**
Median	49.30	49.80
Mean	49.90	49.80
SD	3.50	2.77
Minimum	43.30	41.50
Maximum	59.30	60.70
N	26	1310

A large sample two-sided two-sample test of the null hypothesis that the expected anthropometric measurements were the same for the Egress Study subjects and for the Marine Corps (based on the two samples of 26 and 1356) was conducted for each of the eight anthropometric measurements. Of the eight

hypothesis tests, only two were rejected: the test for mean shoulder circumference with p-value 0.0201 and the test for the mean waist circumference with p-value .0049. Two of the 26 Egress Study subjects, subjects 6 and 20 had unusually large shoulders with circumference of 142.05 cm and 131.90 cm, respectively. Summary statistics of shoulder circumference for the remaining 24 subjects are given in Table 6. The distribution of shoulder circumference of the 24 subjects is comparable to that of the Marine Corps sample. The mean waist circumference of the Egress Study subjects is sufficiently smaller than that of the Marine Corps sample to reject the null hypothesis that their expected values are equal. However, the difference between 88.40 - 83.85 = 4.55 cm with a standard error of 1.49 is very small and not of practical significance to this study.

In general, the anthropometric measurements of the Egress Study subjects are comparable to that of the general Marine Corps.

2. Equipped Measurements

Broadbent, Cornelius, Talebi and Playter (2009) used three-dimensional CAD models of Marines in the 5^{th}, 50^{th} and 95^{th} percentiles based on size carrying a rifle, rifle with grenade launcher, pistol and a Squad Automatic Weapon (SAW) medium machine gun. Figure 15 shows a 50^{th} percentile combat-loaded Marine rifleman. Figure 16 shows 5^{th}, 50^{th} and 95^{th} percentile Marines sitting side-by-side. Broadbent et al. (2009) also included weight tables for combat loaded Marines with each weapon for all three percentiles. The AAV Egress Study weighed subjects with a slightly different combat load set. However, the itemized list of weights found in Broadbent et al. (2009) allowed for subtraction of the items not present for the Egress Study. Table 12 shows a comparison of weights without weapon from the Egress Study with those computed from the Broadbent et al. (2009) representing the general Marine Corps population.

Figure 15. 50th percentile Rifleman (from Broadbent et al., 2009)

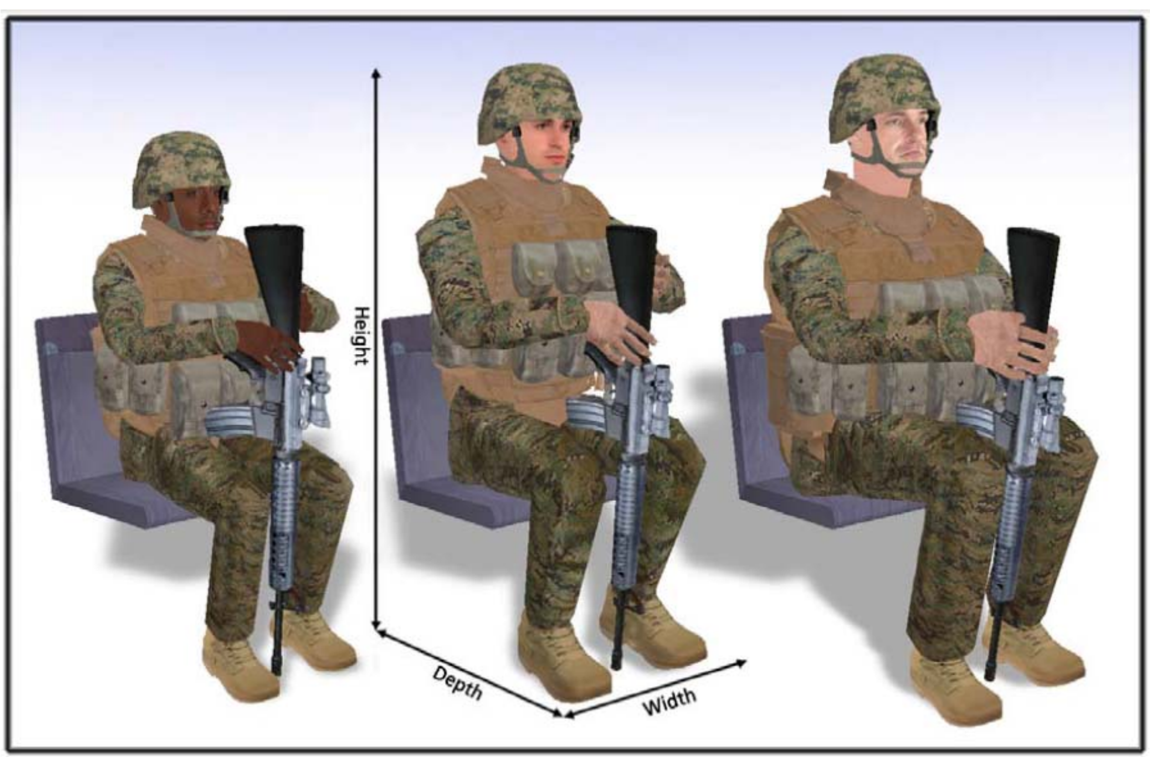

Figure 16. 5th, 50th and 95th percentile Marine rifleman (from Broadbent et al., 2009)

Table 12. Summary Statistics of Weights with Equipment but without Weapon (from Broadbent et al., 2009)

Equipped Weight Comparison		
Percentile	**Egress Study**	**Marine Corps**
5^{th}	190.80	177.85
50^{th}	220.50	226.62
95^{th}	278.30	307.89
Minimum	184.80	Unavailable
Maximum	292.00	Unavailable
N	26	Unavailable

Table 12 shows that the Egress Study subjects' weights were within the 5^{th} to 95^{th} percentiles of the Marine Corps weights. With only a six-pound difference between the median weights of the two groups, the combat loaded Egress Study subject weights resemble those of the Marine Corps population.

D. DESCRIPTIVE STATISTICS

After the experiment, data were screened to ensure accuracy. Time stamped video served as a check for any disputed data point. Three data sheets from three different recorders were compared. Any data point found different from the same data point in another data set was reviewed by watching the video. The data set recorded by the experimenter sitting on top of the sinking AAV was the most accurate, having only to be corrected one time. The following statistics serve to describe the results of the response variables and factors used in the AAV Egress Study.

1. Response Variable

For each trial, three time variables were recorded: Egress Time, Transfer Time and Load Time. Of these, Egress Times is the primary response variable. Load Times provided data for the Seatbelt factor and served as a response variable in a parallel study. Transfer Times are the time to egress plus the time to

transfer to a recovery vehicle. An additional response variable of Snags provides further insight into the experiment's results and is discussed later in the chapter.

Figure 17 shows a histogram of the distribution of Egress Times across all 216 trials. The overall mean is 98.77 seconds (1:39), compared to the median of 76.6 seconds (1:17). There were four extreme Egress Times. Excluding them reduces the range of Egress Times by over two minutes (370–248.4 = 121.6 seconds), however does little to change the mean or median. Table 13 gives summary statistics for Egress Times with and without extreme values. Each extreme Egress Time corresponds to a different treatment with only one level in common; all four involved subjects evacuating with their weapon through the forward three hatches (Take3).

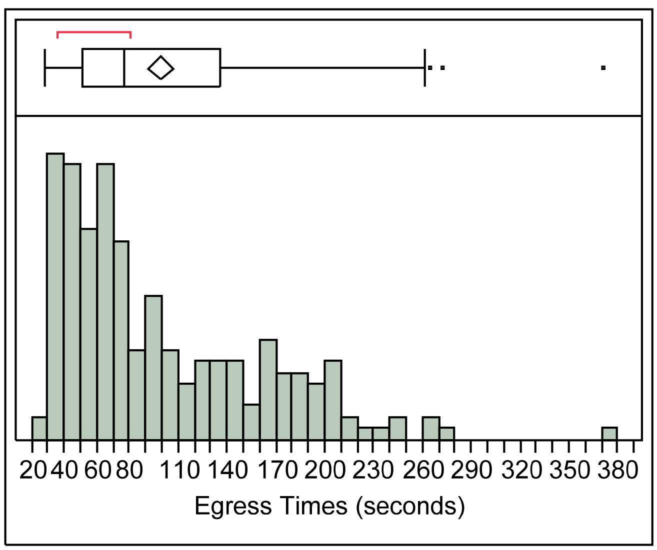

Figure 17. Distribution of Egress Times in seconds

Table 13. Summary Statistics of Egress Times and without extreme values

Egress Times Summary		
Statistic (sec)	**Egress Times**	**W/O Extreme Values**
Median	76.60	74.80
Mean	98.78	95.14
SD	61.41	55.54
Minimum	28.70	28.70
Maximum	370.00	248.40
N	216	212

The slow sink scenario requires subjects to transfer to a recovery vehicle. The rapid sink scenarios force subjects to jettison themselves from the sinking vehicle as quickly as possible. Safety constraints would not allow subjects to jump from the 11-foot high vehicle in the test bay; therefore, subjects had to transfer during rapid sink scenarios as well. Table 14 shows summary statistics for Egress and Transfer Times and for Egress Times subtracted from Transfer Times (Transfer–Egress). Figure 18 provides a histogram of the difference between Egress Times and Transfer Times across all 216 trials. The average time it took subjects to transfer from the top of the sinking vehicle to the recovery vehicle was 3.88 seconds with a median of 3.7 seconds. The experiment took place on land, so the presence of undulations due to sea state did not exist, making the transfer very uneventful. Because Transfer Times-Egress Times are small giving a 0.99 correlation between Egress Times and Transfer Times and because transfers only pertain to slow sink scenarios, we used Egress Times rather than Transfer Times as the response variable.

Table 14. Comparison between Egress and Transfer Times

Egress vs. Transfer Times Summary			
Statistic (sec)	**Egress Times**	**Transfer Times**	**Transfer - Egress**
Median	76.60	79.80	3.70
Mean	98.78	102.66	3.88
SD	61.41	61.28	1.22
Minimum	28.70	33.10	1.10
Maximum	370.00	372.80	9.00
N	216	216	216

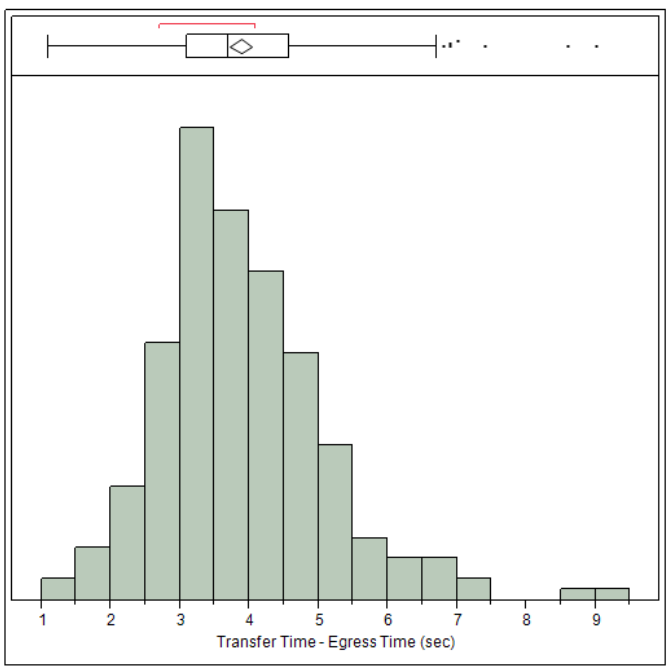

Figure 18. Distribution of Transfer–Egress in seconds

2. Factors

The experimental design described in Chapter III contained six factors. In order to balance the design, two pairs of factors are combined leaving four factors overall. Those factors are Illumination, Passengers, Armor||PFD and Weapons/Route.

a. Illumination

The Illumination factor has two levels: Daylight and Restricted. There were 36 treatments associated with each level, totaling 108 trials. Table 15 provides the summary statistics of Egress Times by Daylight vs. Restricted. Figure 19 shows the boxplots of Egress Times for Daylight and Restricted. Figure 19 suggests that there is not much difference in the Egress Times associated with Daylight and Restricted treatments. However, as mentioned in Chapter III, the subjects egressed from a dark compartment to a visible topside in both Illumination levels due to the presence of a floodlight on the recovery vehicle during the Restricted treatments (as per SOP). The presence of the flood light gave over 98% illumination according to a light meter, offering an explanation as to why the times were so close.

Table 15. Illumination Factor Summary Statistics

Illumination Summary		
Statistic/Level	**Daylight**	**Restricted**
Median	75.80	78.40
Mean	96.90	100.65
SD	59.39	63.59
Minimum	28.70	30.50
Maximum	264.00	370.00
N	108	108

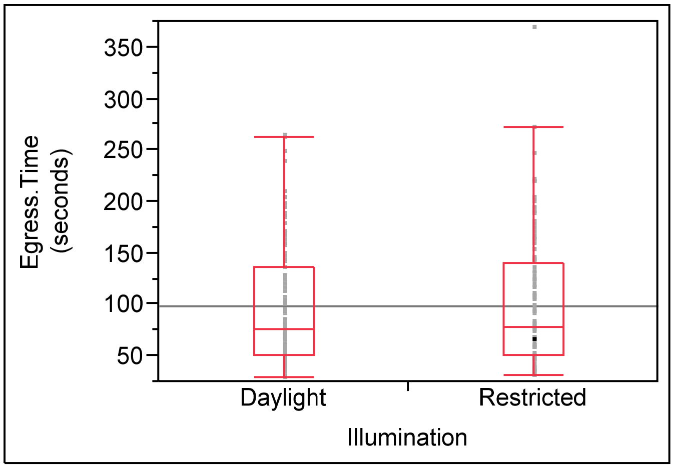

Figure 19. Boxplots of Daylight and Restricted Egress Times with the grand mean Egress Time (98.78 sec) plotted in black

b. Passengers

The Passengers factor has two levels of “17” and “21” representing the number of embarked infantry the AAV is carrying not including the three crewmen. There were 36 treatments associated with each level, totaling 108 trials. Table 16 gives summary statistics for the Egress Times associated with 17 and 21 subjects. Figure 20 shows the boxplots of Egress Times for 17 and 21 subjects.

Table 16. Passengers Factor Summary Statistics

Passenger Summary		
Statistic/Level	**17**	**21**
Median	70.85	87.75
Mean	88.67	108.88
SD	52.62	67.85
Minimum	28.70	28.70
Maximum	264.00	370.00
N	108	108

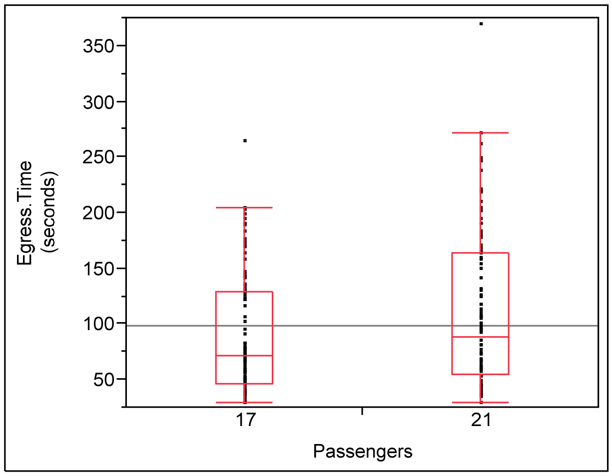

Figure 20. Boxplots for 17 and 21 Passengers Egress Times with the grand mean Egress Time (98.78 sec) plotted in black

c. Armor||PFD

The Armor||PFD factor has three levels: DropLPU-32, KeepLPU-32 and KeepHESP. There were 24 treatments associated with each level, yielding 72 trials per treatment. Table 17 shows summary statistics for Egress Times for each level. Figure 21 shows the boxplots of Egress Times for all three levels. The Egress Times for DropLPU-32 level tend to be faster than the Egress Times for the KeepLPU-32 and KeepHESP levels, while Egress Times for the KeepLPU-32 and KeepHESP levels seem to be similar.

Table 17. Armor||PFD Factor Summary Statistics

Armor||PFD Summary			
Statistic/Level	**Drop LPU-32**	**Keep LPU-32**	**Keep HESP**
Median	68.20	73.30	85.90
Mean	82.49	101.54	112.30
SD	43.02	63.38	71.39
Minimum	30.50	28.70	28.70
Maximum	204.00	271.30	370.00
N	72	72	72

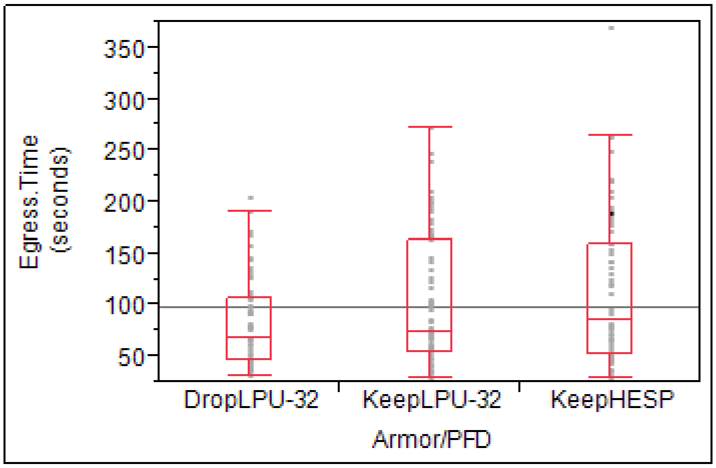

Figure 21. Boxplots of Armor||PFD Egress Times with the grand mean Egress Time (98.78 sec) plotted in black

d. Weapon||Route

The Weapon||Route factor contains the levels Take1, Take3, Take4, Leave2, Leave3 and Leave5. There were 12 treatments associated with each level, giving 36 trials per level. Table 18 shows the summary statistics for Egress Times. Figure 22 shows the boxplots of Egress Times for each level. The middle 50% of Egress Times (represented by the boxes in Figure 22) for the Leave3 level and all Egress Times for the Take3 level are greater than the grand mean Egress Times indicating generally slow Egress Times when subjects are forced to egress through the forward three hatches.

Table 18. Weapon||Route Factor Summary Statistics

Weapon||Route Summary						
Statistic/Level	**Leave5**	**Leave2**	**Take4**	**Take1**	**Leave3**	**Take3**
Median	39.60	46.25	67.40	87.75	138.25	189.20
Mean	42.08	49.66	72.34	91.46	142.90	194.21
SD	10.12	16.67	17.87	22.43	42.62	47.08
Minimum	28.70	34.30	50.90	65.20	76.60	128.40
Maximum	66.00	124.60	125.00	153.50	246.20	370.00
N	36	36	36	36	36	36

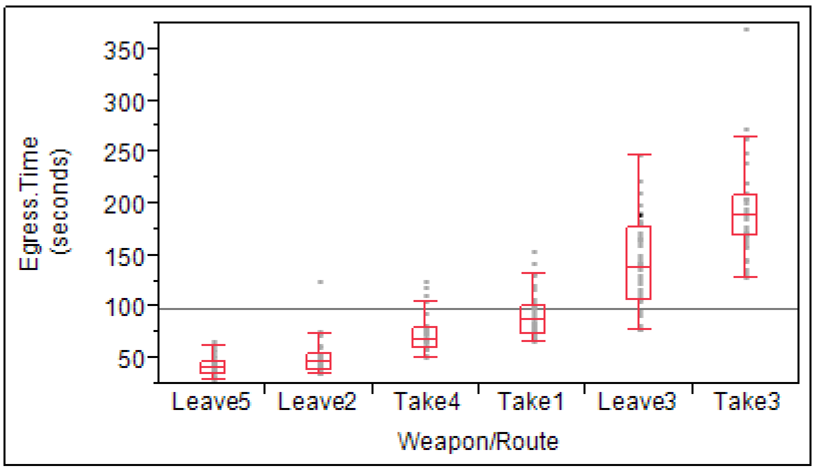

Figure 22. Boxplots for Weapon||Route Egress Times with the grand mean Egress Time (98.78 sec) plotted in black

E. INFERENTIAL STATISTICS

This section examines the data using ANOVA to make inferences about emergency egress times from an AAV as a function of the conditions varied in the experiment, namely the illumination, the number of subjects, the type of Armor and PFD combination, and the type of Weapon and Route combination.

1. Model

The experimental design is a full factorial design. With treatment replication, we were able to fit a full factorial ANOVA model with all main effects, and all interactions. In the full factorial model, there are four main effects, six two-way interactions, four three-way interactions and one four-way interaction. The response variable Egress Times does not have constant variance. The variability of Egress Times is greater for trials with larger mean Egress Times. This can be seen in the fan shaped pattern of residuals in Figure 23. It can also be seen more directly in Figure 24, which plots the Egress Times for all three replications of the 72 treatments. The black and blue lines show the overall mean and median Egress Time, respectively. It becomes obvious that the treatments involving the forward three hatches (Leave3 and Take3) not only have the larger times but the difference between those times is greater.

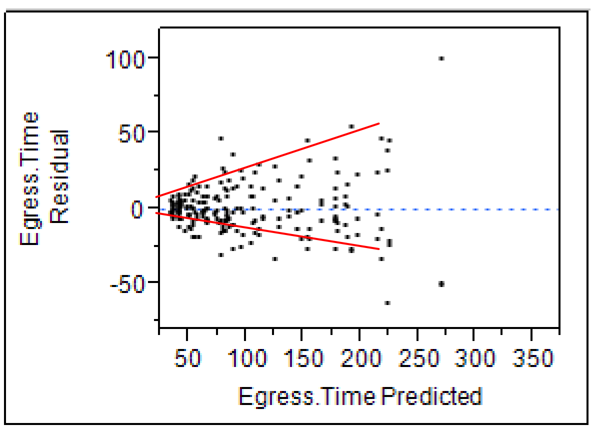

Figure 23. Residuals vs. Predicted Values based on an ANOVA fit with Egress Times against all factors and their interactions

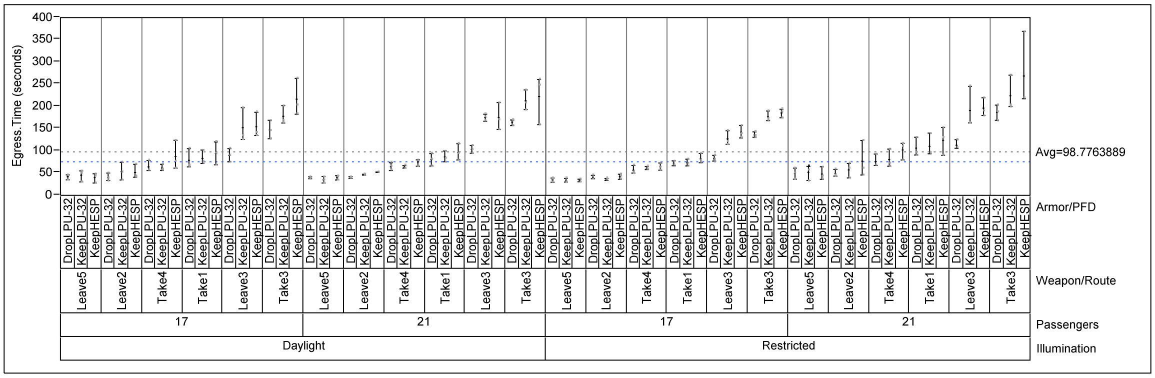

Figure 24. Variability of Egress Times by Treatment (Mean: black dotted line, Median: blue dotted line)

To stabilize the variance, we transform the response variable. The log transformation of Egress Times provides an adequate variance stabilizing transformation as can be seen in Figure 25, which shows the plot of the residuals from the full factorial model fit with the log of Egress Times as the response variable against the corresponding predicted values. Further confirmation is provided by the Box-Cox transformation. The estimated power for the Box-Cox transform has a 95% confidence interval of [-0.2, 0.1], which includes zero, the power that corresponds to a log transformation.

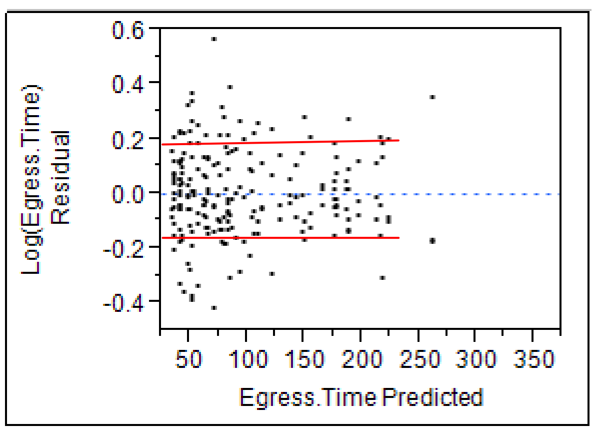

Figure 25. Log of Egress Times Residual by Predicted Egress Times

2. Confounding Factors

Considering the experiment was not completely randomized, confounding factors were introduced as the experiment unfolded. Figure 26 reveals a pattern in the residuals showing a negative slope over the course of the experiment indicating there is dependence in the observations. In order to account for the systematic trend shown in Figure 26, we add the factors Replication Order (which records the order of the trial in each treatment), Seatbelts (which indicates if the trial was part of a parallel study requiring seatbelts), and Time of Day (TOD).

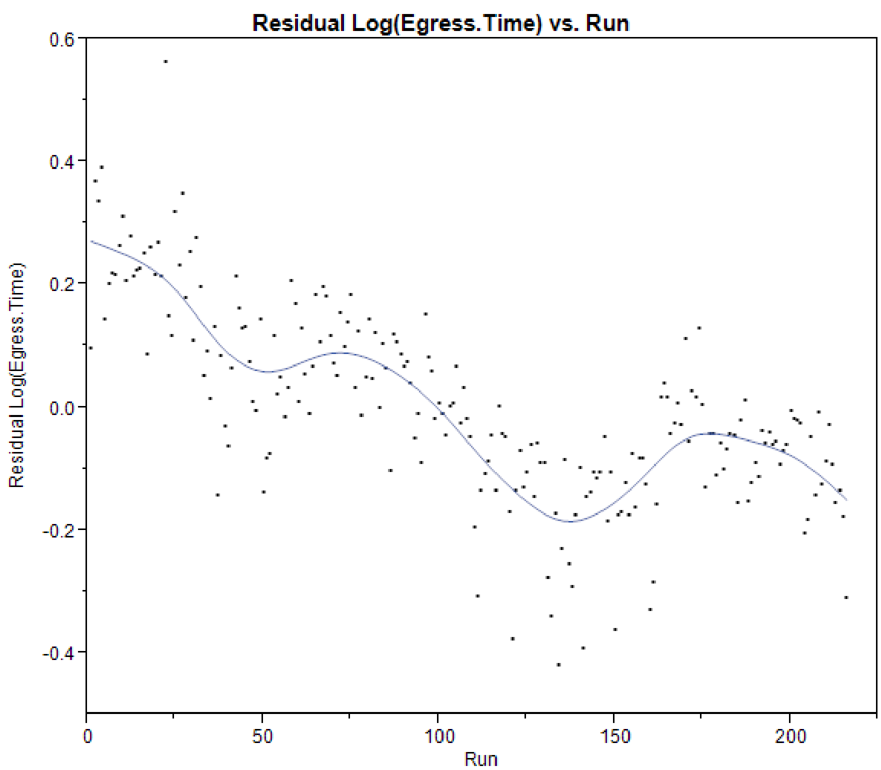

Figure 26. Log of Egress Times by Run Order

3. Replication Order

The decreasing residuals based on Run Order, suggests that the test subjects learned as the experiment progressed. Randomization of the treatment replications attempted to reduce learning effects. Looking at the means of each treatment in Table 19, one can plainly see that learning occurred (Note: A, B and

C represent the 1st, 2nd and 3rd replication of a specific treatment). Figure 27 shows the residuals for each treatment decreasing with each replication.

Table 19. Replication Order Summary Statistics

Replication Order Summary			
Statistic/Order	**A**	**B**	**C**
Median	95.20	72.80	67.20
Mean	115.10	95.40	85.90
SD	70.10	57.30	52.70
Minimum	36.90	30.70	28.70
Maximum	370.00	248.40	218.60
N	72	72	72

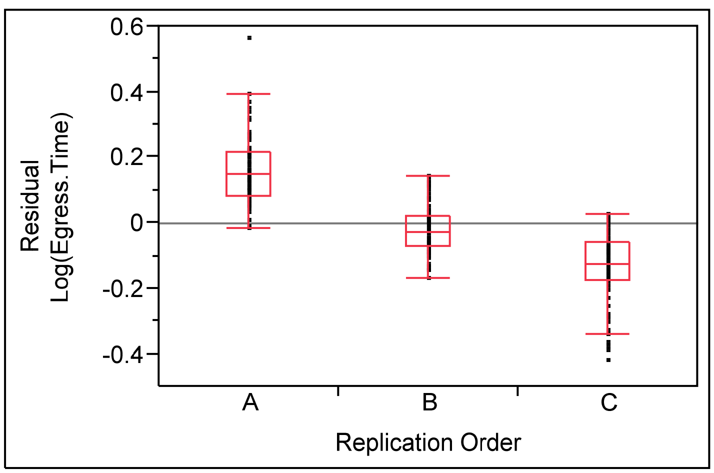

Figure 27. Boxplots of Residuals by Replication Order

One possible explanation may lie within the group of test subjects. Upon arrival, subjects answered demographic questions including their experience with AAVs. With the exception of the crewmen, the subjects had almost no experience. All subjects acting as embarked infantry, had less than ten months in the service and had never worked together. Adding replication order as a

confounding factor, with levels A, B and C, accounts for some of the trends seen in Figure 27. Figure 28 plots the residuals of the new model for Log Egress Time, which included the factor Run Order. Including Run Order as a factor removes much of the trend evident in Figure 28 however, the large dip in the middle (indicated by the red circle) of the plot in Figure 28 suggests additional confounding.

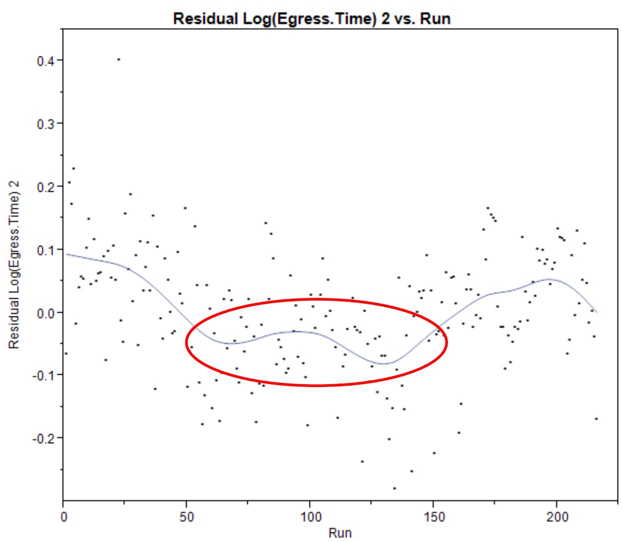

Figure 28. Log Egress Time Residuals (with Replication Order) against Run Order

4. Seatbelts

We note that out of eight test days, the middle four contained trials for the parallel study involving seat belts. On test days 3, 4, 5 and 6 there were three seat belt trials in the beginning that served as practice trials for the main experiment. Table 20 shows the Egress Times for the Seat Belt Factor. Figure 29 plots the difference between the residuals for trials with and without the presence of seat belt trials.

Table 20. Seat Belt Factor Summary Statistics

Seat Belt Summary		
Statistic/Level	**Present**	**Not Present**
Median	74.15	78.70
Mean	93.29	104.26
SD	56.97	65.36
Minimum	28.70	28.70
Maximum	261.5	370.00
N	108	108

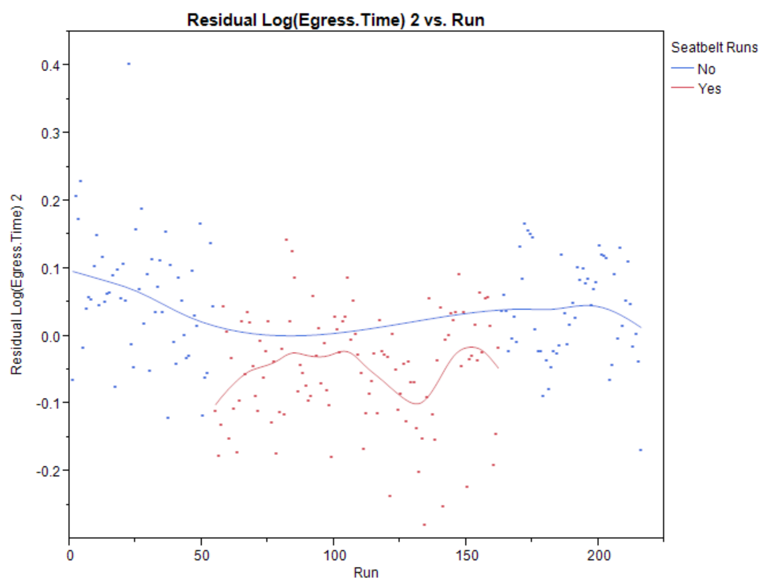

Figure 29. Residuals plotted against Run Order with smoothers fit to residuals corresponding to treatments with (red) and without (blue) seatbelts

5. Time of Day

Another potential confounding factor is time of day for each trial. Experimentation took place between the hours of 0800–1100 and 1300–1600 (see Appendix F for run matrix). Figure 30 reveals a TOD effect in the later part of the experiment. Table 21 shows the Egress Times for TOD Factor.

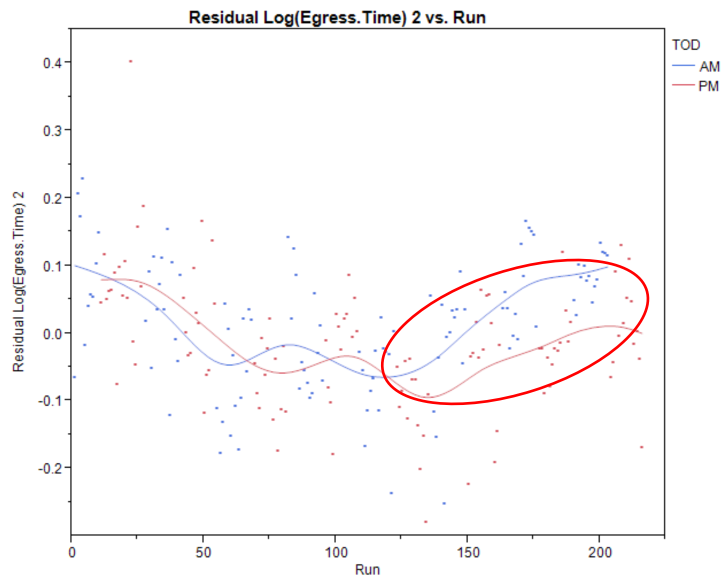

Figure 30. Residuals plotted against Run number with smoothers fit to residuals corresponding to Time of Day AM (red) and PM (blue)

Table 21. TOD Factor Summary Statistics

Time of Day Summary		
Statistic/Level	**AM**	**PM**
Median	74.80	76.75
Mean	98.80	98.75
SD	60.02	63.05
Minimum	30.70	28.70
Maximum	271.30	370.00
N	108	108

6. Adjusting the Model

To reduce the effects of seat belts and TOD, as well as possible interactions, we fit a model containing the original factors (Illumination, Passengers, Armor||PFD, Weapon||Route) and the potential confounding variables (Replication Order, Seat Belts, TOD) with interactions. Figure 31 shows the residuals for the model fit plotted against Run Order. With the confounding variables there no longer appears to be a trend in the residuals with run number.

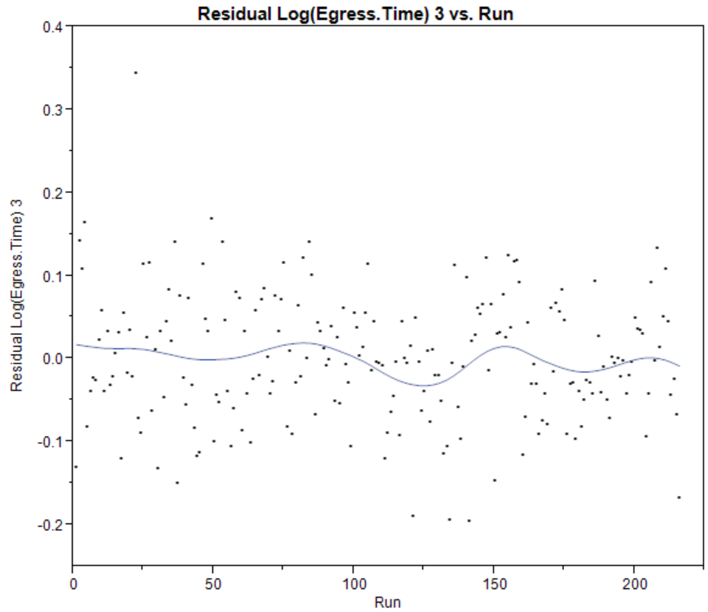

Figure 31. Adjusted model residuals against Run Order

The outlier in Figure 32, with a residual of 0.344, corresponds to run 22. However, this observation is not unduly influential. Its Cook's Distance is less than 0.15 as can be seen by the plot of Cook's Distance in Figure 32. Figure 32 also shows that none of the other observations is influential for this model. All Cook's Distances in Figure 32 are well below 1.0. In addition, residual plots for the adjusted model with the confounding variables confirm that the ANOVA modeling assumptions are met (i.e., errors are well modeled as independent, identically distributed normal random variables with expected value zero and constant variance).

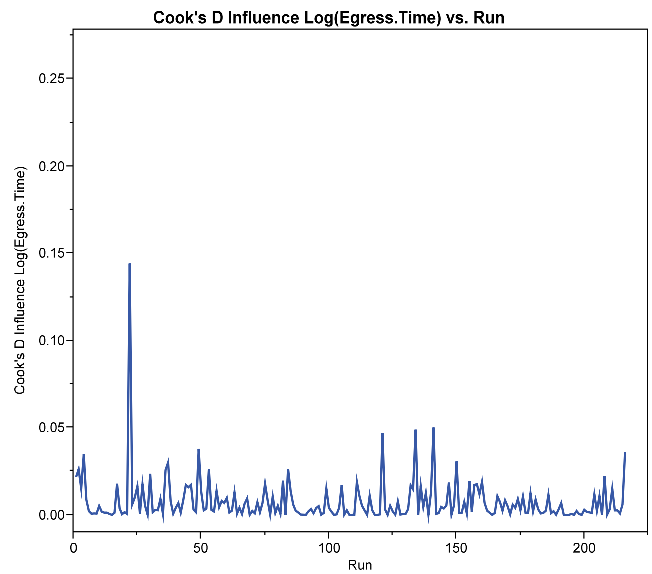

Figure 32. Cook's Distance against Run Order

7. Factor Selection

The next step is to remove unnecessary terms. Table 22 shows the model of the main effects and all interactions for both the factors and confounding variables. Backwards elimination starting with the full model (including confounding factors) yields the model fit given in Table 23.

Table 22. Model before Factor Elimination (Full Model)

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Illumination	1	1	0.013757	1.4670	0.2280
Passengers	1	1	0.941004	100.3463	<.0001*
Illumination*Passengers	1	1	0.301431	32.1439	<.0001*
Weapon/Route	5	5	62.835263	1340.119	<.0001*
Illumination*Weapon/Route	5	5	0.038021	0.8109	0.5439
Passengers*Weapon/Route	5	5	0.082410	1.7576	0.1259
Illumination*Passengers*Weapon/Route	5	5	0.084014	1.7918	0.1187
Armor/PFD	2	2	2.087863	111.3222	<.0001*
Illumination*Armor/PFD	2	2	0.008950	0.4772	0.6216
Passengers*Armor/PFD	2	2	0.005860	0.3125	0.7322
Illumination*Passengers*Armor/PFD	2	2	0.014161	0.7550	0.4720
Weapon/Route*Armor/PFD	10	10	1.517117	16.1782	<.0001*
Illumination*Weapon/Route*Armor/PFD	10	10	0.056900	0.6068	0.8060
Passengers*Weapon/Route*Armor/PFD	10	10	0.045301	0.4831	0.8986
Illumination*Passengers*Weapon/Route*Armor/PFD	10	10	0.131485	1.4021	0.1859
Replication Order	2	2	3.307382	176.3455	<.0001*
Seatbelt Runs	1	1	0.490972	52.3560	<.0001*
Replication Order*Seatbelt Runs	2	2	0.065042	3.4679	0.0340*
TOD	1	1	0.066921	7.1363	0.0085*
Replication Order*TOD	2	2	0.027976	1.4916	0.2287
Seatbelt Runs*TOD	1	1	0.011204	1.1948	0.2763
Replication Order*Seatbelt Runs*TOD	2	2	0.005485	0.2925	0.7469

Table 23. Model after Factor Elimination

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Illumination	1	1	0.040242	4.2846	0.0398*
Passengers	1	1	1.855489	197.5561	<.0001*
Weapon/Route	5	5	63.532583	1352.877	<.0001*
Armor/PFD	2	2	2.081858	110.8289	<.0001*
Illumination*Passengers	1	1	0.301431	32.0937	<.0001*
Weapon/Route*Armor/PFD	10	10	1.528373	16.2728	<.0001*
Replication Order	2	2	3.356893	178.7061	<.0001*
Seatbelt Runs	1	1	0.681899	72.6025	<.0001*
TOD	1	1	0.076196	8.1127	0.0049*
Replication Order*Seatbelt Runs	2	2	0.054432	2.8977	0.0576

8. Interpretation

The model in Table 23 has interactions between Illumination and Passenger factors as well as the Armor||PFD and Weapon||Route factors. Figure 33 takes a closer look at the interaction between Illumination and Passengers. The difference in mean Log Egress Times for 17 to 21 embarked infantry is only slight during daylight conditions shown by the near flat blue line. During restricted conditions, the difference is significant as seen by the positively sloped red line.

The most interesting difference is between Restricted17 and Daylight17, where it shows Restricted17 has overall lower mean Log Egress Times than Daylight17.

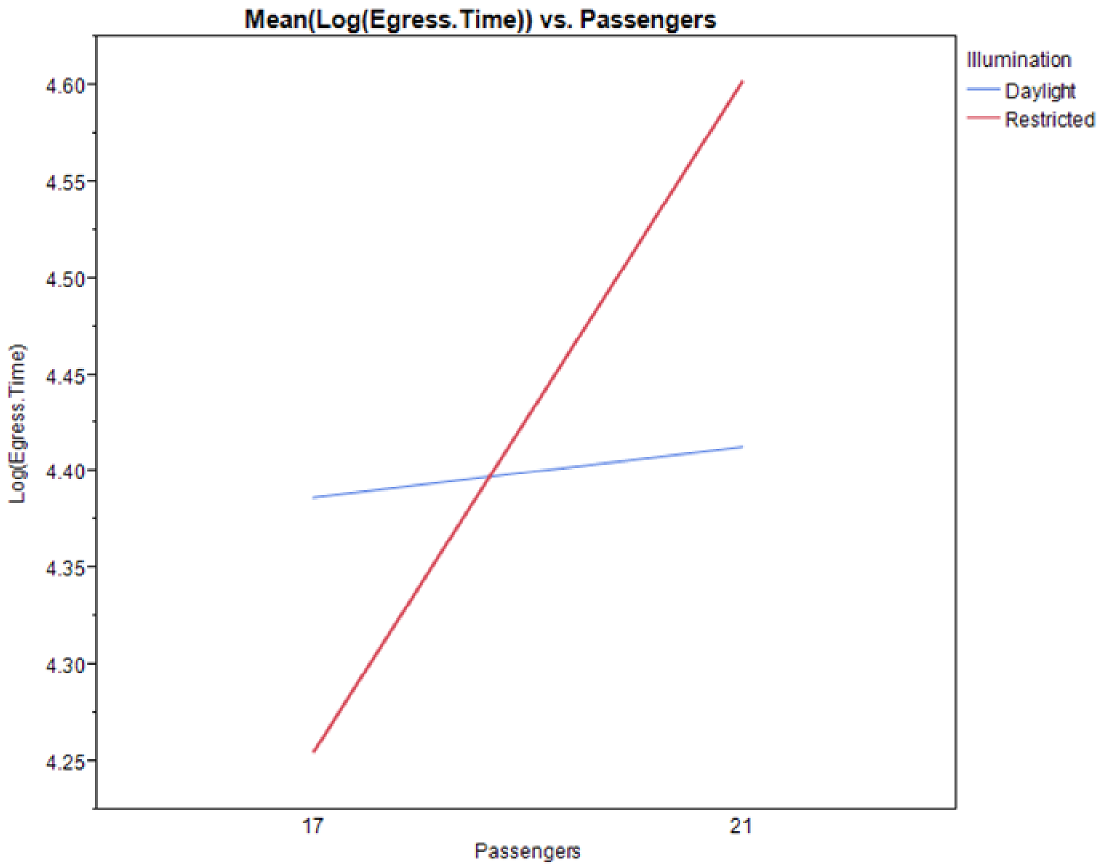

Figure 33. Interaction Plot of Mean Log Egress Time by Illumination and Passengers

Figure 34 gives the interaction plot when Illumination and Passengers are concatenated to create one factor with four levels against Replication Order. The plot shows a spike in Treatment A for Daylight17, marked by the red circle. A Tukey HSD (Honestly Significant Difference) multiple comparison test conducted in the presence of other factors found that in fact Restricted17 had lower Egress Times than Daylight17 regardless of Replication Order. Further, Daylight17 and Daylight21 were not significantly different, while Daylight21 and Restricted21 were. Thus, when accounting for the results with differences in replication order we still see differences in Illumination and Passengers factors.

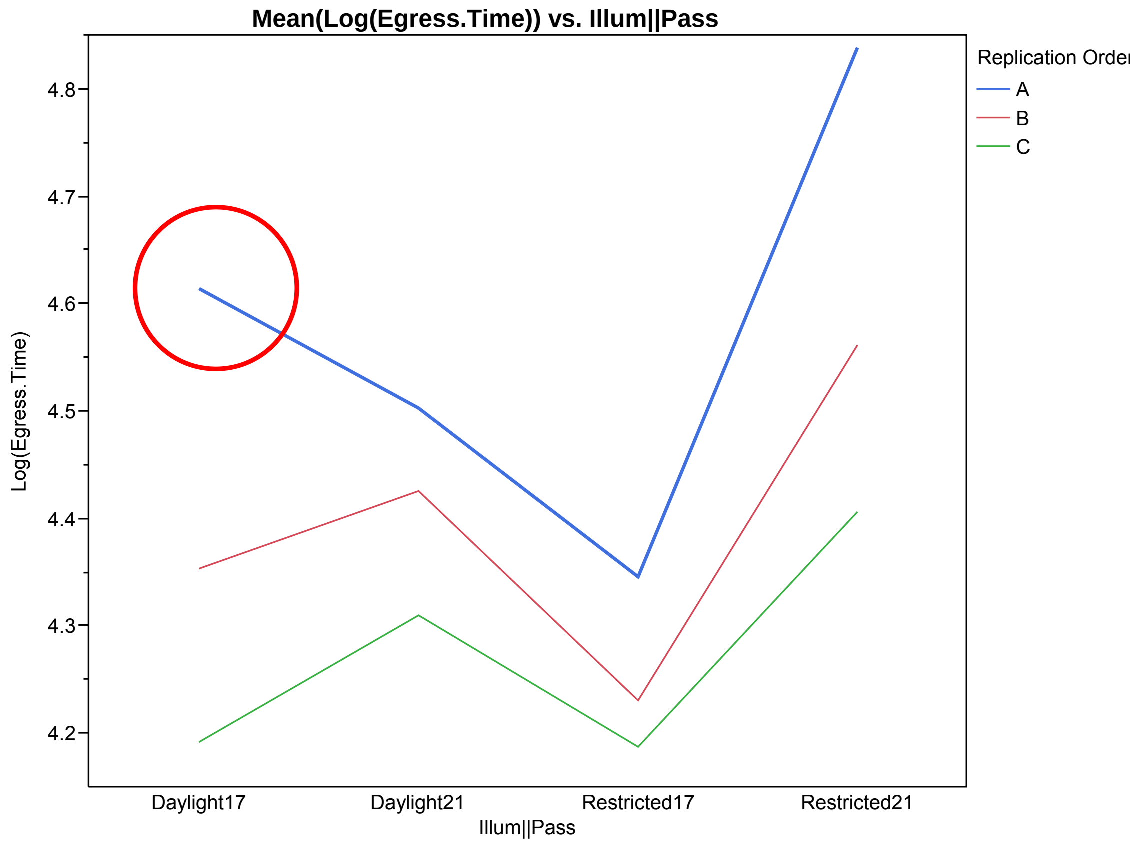

Figure 34. Interaction Plot of Mean Log Egress Times by Illumination||Passengers and Replication Order

Figure 35 shows little interaction between Armor||PFD and Weapon||Route. KeepHESP mean Egress Times are slightly greater than those of KeepLPU-32. This makes sense; the HESP device went over top of the body armor while the LPU-32 fit underneath causing less bulk and lower susceptibility to snags. The DropLPU-32 mean Egress Times are faster than those for the other two levels of Armor||PFD and for all Weapon||Route, with one exception: the Leave5 level. For the Leave5 level, all subjects left their weapons and egressed through the nearest hatch as quickly as possible, presenting almost no chance for snags. In the Drop Armor||PFD treatments, subjects had to first drop their body armor delaying their egress. Thus, the Keep levels have slightly slower Egress Times. For the Leave2 level, the driver and troop commander dropped their body armor before crawling back through to the cargo hatches, giving them

a slimmer profile and reducing the chance for snags. Take4 trials are similar to Leave5, however the subjects are restricted from using the portside cargo hatch and they have to take their weapons. The Take1 level is the same as the Take4 level except the driver and troop commander must make their way to the starboard cargo hatch while carrying their weapon. The biggest differences in mean Log Egress Times occur in the Leave3 Weapon||Route level. During the Leave3 and Take3 treatments, subjects in the back move to the forward three hatches based on a simulated inability to open the cargo hatches. Only the driver and troop commander's hatches are available for egress. The driver's hatch sits forward of the troop commander's hatch, so the subjects (with the exception of the driver and crew chief) egress through the troop commander's hatch. In a Leave3, the subjects leave their weapon. The DropLPU-32 level through the troop commander's hatch has an average Egress Time of 98.3 seconds. The Keep levels have an average Egress Time of 162.4 seconds for KeepLPU-32 and 168.1 seconds for KeepHESP. With over a minute difference, it becomes apparent that regardless of PFD type, wearing body armor in a situation that forces the subjects to move through the forward hatches causes a significant bottleneck.

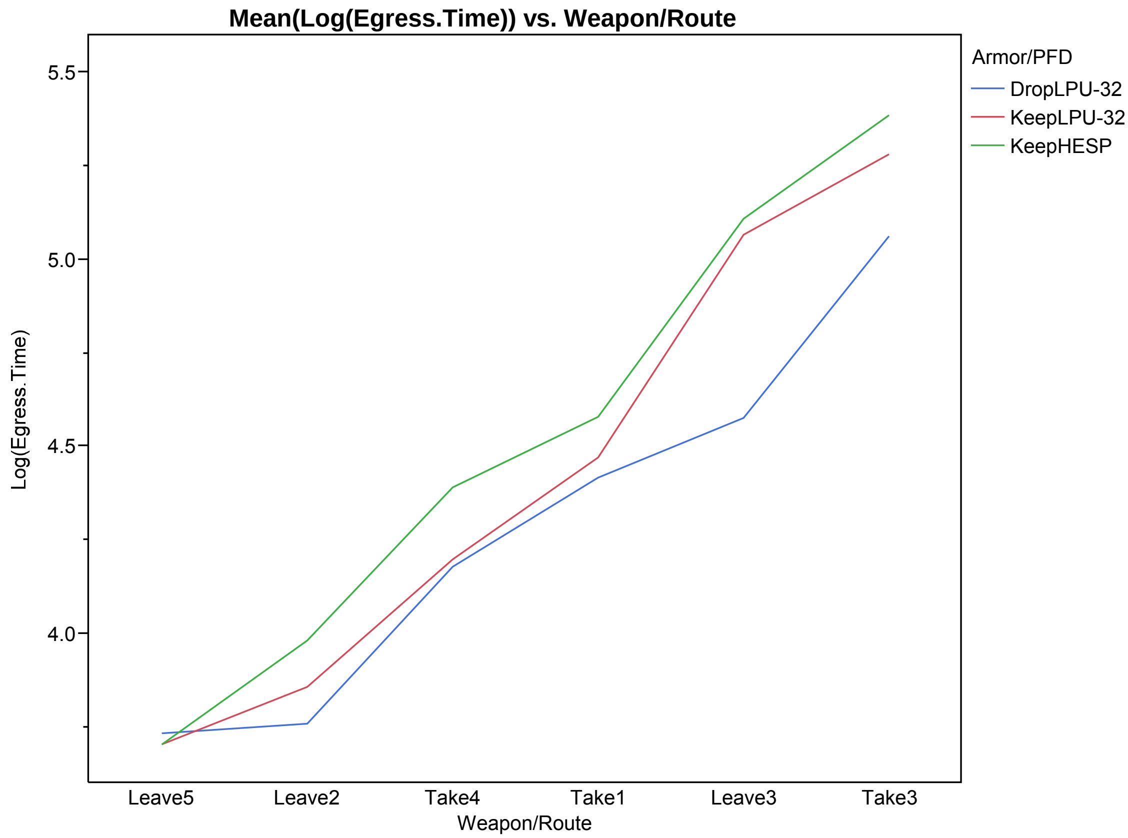

Figure 35. Interaction Plot Armor||PFD against Weapon||Route

A Tukey HSD test performed on Weapon||Route and Armor||PFD in the presence of the other factors yielded significant differences in the levels of the two combined factors. All six levels of Weapon||Route had significant differences. Forward hatch treatments had the highest Egress Times, followed by single cargo hatch treatments. Treatments that involved both cargo hatches yielded the lowest times. The Tukey HSD test for Armor||PFD yielded DropLPU-32's Egress Times were significantly lower than Keep/LPU-32, which in turn were lower than those of KeepHESP. The test infers that dropping body armor decreases Egress Time. Thus, dropping body armor decreased Egress Times and wearing the LPU-32 PFD tended to yield smaller Egress Times than wearing the LPU-41/SRU-43 HESP.

Figure 36 shows Replication Order A has the largest mean Log Egress Times followed by Replication Order B then C. The presence of seatbelt trials did

not start during Replication Order A until Run number 69. At this point, 50 trials from Replication Order A and 18 trials from Replication Order B had been completed. The seatbelt trials continued through the rest of Replication Order B until 18 trials into Replication Order C. This left 54 remaining trials from Replication Order C that were not a part of the seatbelt trials. Figure 36 shows the interaction between the confounding variables Replication Order and Seatbelts.

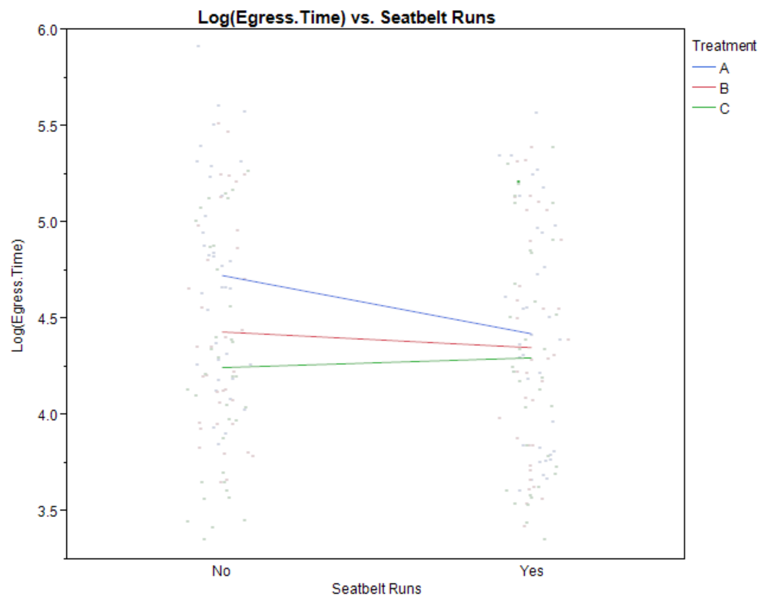

Figure 36. Interaction Plot of Mean Log Egress Times by Seatbelts and Replication Orders

F. SNAG DATA

After the first day of testing, it became apparent that snags occurred often and required recording. A protocol, developed to record the nature of each snag, started on the second testing day with run 28. Table 24 shows the summary statistics for snags counts by subject and by run. Table 25 gives the summary statistics of snags based on Armor||PFD treatment. Although KeepLPU-32 had a significantly larger average number of snags than KeepHESP, subjects reported having more trouble with the KeepHESP configuration. As mentioned in Chapter

III, subjects only knew if they were dropping or keeping their armor just before they were given the order to exit the AAV during the LPU-32 treatments; however, they had advance warning and practice when conducting the KeepHESP treatments. DropLPU-32 had as many subjects getting stuck in the flotsam that developed when they dropped their armor as they did snags from the KeepLPU-32.

Table 24. Summary Statistics for Total Number of Snags by Subjects and by Run

Snag Counts (Runs 28 to 216)		
By Subject	Median	11
	Mean	16.80
	SD	16.20
	Min	0
	Max	58
By Run	Median	2
	Mean	2.30
	SD	2.45
	Min	0
	Max	11

Table 25. Summary Statistics for Number of Snags by Armor||PFD

Armor||PFD Snag Summary			
Statistic/Level	**Drop LPU-32**	**Keep LPU-32**	**Keep HESP**
Median	2	3	2.5
Mean	1.78	3.57	3.43
SD	0.98	2.59	2.48
Minimum	1	1	1
Maximum	5	11	10
Snag Total	37	53	56

Table 26 shows the top five snag counts by subjects with several revealing measurements. The two highest snag counts belonged to subjects 6 and 20. These individuals ranked either first or second in every anthropometric category. Subject 6 also carried the only M240G, a medium machine gun weighing 11 Kg (24.2 lbs.) and 120.65 cm (47.5 inches) long. The next largest weapon carried was the M249 SAW weighing 6.88 Kg (15.2 lbs.) and 103.8 cm (40.9 inches) long. The subjects with SAWs did not seem to have an unusual number of snags. Subjects 4, 11, and 18 had the next highest number of snags. All three subjects' anthropometric measurements fell near the middle of the sample with the exception of the bideltoid breadth of subjects 4 and 11. To view all anthropometric measurements for the sample see Appendix D.

Table 26. Top Five Sang Counts based on Subject Anthropometric Measurements

Top Five Snag Count						
Subject ID	**Snags**	**PT vs. CL Weight**	**Weapon**	**Total Weight**	**PT Chest Depth**	**PT Bideltoid Breadth**
6	58	239(1st)/292(1st)	M240G	316.2	27.6(2nd)	59.25(1st)
20	51	228(2nd)/278(2nd)	M4/203	289	28.35(1st)	55.75(2nd)
4	41	169(15th)/224(10th)	M4	231.5	24.7(6th)	55.6(3rd)
11	40	171(14th)/220(14th)	M4	227.5	23.45(14th)	53.65(4th)
18	39	172(13th)/214(16th)	M4	221.5	23(17th)	48.25(16th)

Table 27 shows the distribution of the number of snags based on Weapon||Route. The mean number of snags does not correspond to mean Egress Times as seen in Table 18. However, the total number of snags increases with mean Egress times in Table 18. This suggests that while snags may contribute to an increase in Egress Times based on Weapon||Route it is not the sole factor.

Table 27. Weapon||Route Snag Summary Statistics

Weapon||Route Snag Summary						
Statistic/Level	**Leave 5**	**Leave 2**	**Take 4**	**Take 1**	**Leave 3**	**Take 3**
Median	1	2	2	1.5	4.5	4
Mean	1.38	2.15	2.21	1.75	4.38	4.58
SD	0.65	0.93	1.53	0.94	2.81	2.61
Minimum	1	1	1	1	1	1
Maximum	3	4	6	4	10	11
N	13	20	24	24	32	33

Figure 37 plots the number snags by the factors of Weapon||Route and Armor||PFD. In both cases where the subjects kept their armor on, snags occurred at a greater frequency than dropping armor. KeepLPU-32 had a slightly higher mean number of snags, while KeepHESP had a greater total number of snags and more complaints from the subjects. There is no clear difference in the number of snags when taking or leaving a weapon. It is possible that although subjects had a greater weight burden during Take treatments, other subjects staging on top of the vehicle assisted fellow subjects with their weapons, causing fewer snags to occur. Leave treatments, although less cumbersome for subjects, resulted in additional flotsam, increasing the possibility of snags (this is partially substantiated by subject comments). Additionally, Route had an effect, as seen in Figure 37.

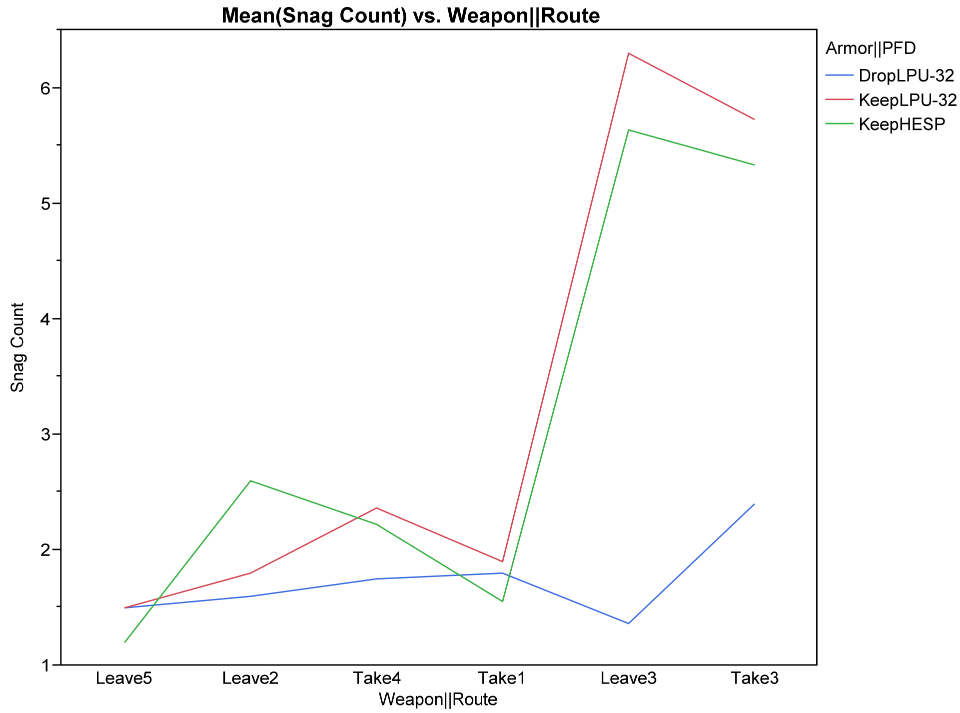

Figure 37. Interaction Plot of Mean Number of Snags for Weapon||Route and Armor||PFD

G. SURVEY ANALYSIS

On the final day of the AAV Egress Study, experimenters walked through the AAV with the subjects and conducted live surveys. Subjects were asked forms of questions. The first asked about the difficulty of egress from the AAV under different conditions on a seven-point Likert Scale. The second asked about individual factor levels. For instance, "Which condition made it more difficult to exit the AAV?" Answers provided included Daylight, Restricted or Same. The only exception was the Route question, which had answers for all five routes. The third provided space for the subject to write a response. A copy of the survey is in Appendix G.

Table 28 gives summary statistics for the first set of questions. The mean responses indicate the severity of a factor level against all other factor levels. In this case, subjects felt leaving their weapon behind allowed for the easiest egress, while using the LPU-41/SRU-43 HESP made egress the most difficult.

Table 28. Summary Statistics for Questions Concerning Difficulty of Egress (Measured on a Seven-Point Likert Scale with 7 corresponding to the most difficult)

Survey Responses (1 through 7 Likert Scale)								
Statistic/Level	**Daylight**	**Restricted**	**17**	**21**	**Take**	**Leave**	**LPU-32**	**HESP**
Median	2	3	2	4	4	1	2	5
Mean	2.16	3.44	2.35	3.95	3.71	1.75	2.38	4.58
SD	1.18	1.56	1.18	1.67	1.27	0.99	1.01	1.32
N	25	25	20	20	24	24	24	24

In the second set of questions, whose results are provided in Table 29, subjects chose which level seemed more difficult, if at all. Response A refers to the first level, while response B refers to the second level. For instance, A refers to Daylight and B to Restricted in the Daylight or Restricted Column. Although Route had five responses, the subjects responded with only Route 3 and Route 4. The individual questions only compare the level within a specific factor. The responses to these questions are consistent with the rest of the Egress Study. Of note, Subjects 17 and 21 said Route 4 (Starboard Cargo Hatch only) felt more difficult because the responsibility to open the hatch fell upon them based on seating arrangement.

Table 29. Summary Statistics Comparing Two Levels (A and B) of Each Factor (subjects reported which factor was more difficult)

Survey Responses (Individual Questions)						
Response	**Daylight or Restricted**	**17 or 21**	**Take or Leave**	**Drop or Keep**	**LPU-32 or HESP**	**Route**
A	0	0	0	1	0	23 (Route3)
B	17	15	22	22	18	2 (Route4)
Same	8	5	3	2	7	N/A
N	25	20	25	25	25	25

V. DISCUSSION

A. INTRODUCTION

As stated previously, the purpose of the present study was to provide the Marine Corps with baseline information concerning the amount of time needed to egress from an AAV under various conditions. Those conditions were dictated by the sponsors of the study. The data were collected in a nearly ideal setting. For example, the AAVs were in a large maintenance bay rather than in a body of water. And, every precaution was taken to ensure the safety of the Marines who served as research subjects This chapter will discuss the implications of the data analysis presented in the previous chapter. The findings of this study can then be compared to future studies that would investigate egressing from the current AAV in more realistic conditions, the upgraded AAV, and the new ACV.

B. RESEARCH QUESTION ONE

The first question asked, “What factors provide Marines in a sinking AAV the best chance for survival?” There were several factors and combinations of factors that were found to be significant. Each of these will be discussed briefly.

1. Illumination

As expected, the data revealed that Marines were able to egress from the AAV faster during daylight conditions than under restricted illumination. Although the difference was statistically significant, the mean times were less than four seconds apart (daylight = 96.90 sec; restricted = 100.65 sec). Illumination levels in the maintenance bay during the restricted condition registered as high as 98%. The illumination provided by the AAV interior lighting and the spotlight on top (which was used because it complied with the SOP) appeared to be sufficient to allow Marines to egress relatively quickly.

2. Passengers

It was not surprising to learn that it took significantly longer to egress from the vehicle when there were 21 (versus 17) embarked infantry in the back of the AAV. The four additional Marines took an average of 20 seconds longer to egress. Adding four infantry passengers and their equipment resulted in all embarked Marines being more cramped and having a more difficult time egressing the vehicle due to the greater amount of flotsam that had to be negotiated to get to a hatch.

3. Armor||PFD

The combinations of armor (drop in place or keep it on) and personal floatation device (LPU-32 or HESP) yielded just three conditions because the relevant SOP states that body armor is not removed when wearing the HESP. Of the three conditions, the fastest egress times were achieved when the body armor was removed and the LPU-32 was worn. On average, it took 20 seconds longer to egress when the body armor was worn with the LPU-32 and 30 seconds longer when the body armor was worn with the HESP. It should be noted that mean times in all three conditions were higher than the median times due to outlier trials when snags occurred. There were more snags (hence, more outliers and slower exit times) when the body armor was worn. Retaining the body armor provides personal protection after leaving the vehicle but impedes the ability to egress from the vehicle because it adds weight, decreases mobility, and increases the likelihood of snags.

4. Weapon||Route

There were six conditions that resulted from combining the factors of weapon and route. These conditions were also driven by SOP. In a slow-sink scenario, Marines are taught to take their weapons when they egress from the AAV. But, in a fast-sink scenario, they are instructed to leave their weapons. Further, in a slow-sink scenario, the SOP states that only one cargo hatch should be opened but in a fast-sink scenario both cargo hatches can be used. The

resulting six conditions were: Take (weapon) 1 (hatch); Take3; Take4; Leave2, Leave3; and, Leave 5.

As expected, the fastest egress times occurred when Marines left their weapons and used all five hatches (mean = 42.08 sec). It took them more than four times longer to egress from the vehicle when they took their weapons and used three hatches. The next slowest egress time occurred when the Marines left their weapons and used three hatches.

The three-hatch conditions are misnomers. The hatches used in this condition are at the front of the vehicle and designated for the driver, the troop commander, and the crew chief. They are much smaller than the two cargo hatches in the rear of the vehicle. Of the three forward hatches, only the troop commander hatch is a viable option for the embarked infantry. The driver's hatch requires the Marines to negotiate a passageway no more than 12 inches wide. The crew chief hatch has a turret cage that must be climbed into before exiting through the hatch. Both of these hatches are nearly impossible to negotiate when wearing body armor and carrying a weapon. Consequently, only the driver and the crew chief used their respective hatches. All other Marines in the vehicle egressed through the troop commander's hatch in the three-hatch conditions.

5. Replication Order

The study consisted of 72 unique trials; each trial was conducted three times. The intent of the researchers was to randomize each set of 72 trials and to finish all trials in the first set prior to moving on to the second and third sets. However, a completely randomized trial set would have taken too long to finish because of the transitions required between certain trials. For example, each time the experimental plan called for a restricted illumination following a daylight trial, a 15–20 minute pause was taken so that the subjects' eyes could adjust to the lighting condition. Therefore trials were blocked in a manner that increased the efficiency of study but resulted in some trials in the 2nd and 3rd sets being conducted before all of the trials in the first set were completed.

The analysis indicated that, in general, egress times improved from the first trial set to the third trial set. This finding, coupled with the survey results and the observations of the researchers, suggest that the Marines were learning throughout the eight days of experimentation. Another factor that may have contributed to improved performance in subsequent trial sets is improved teamwork.

6. Illumination x Passengers

The analysis revealed a significant interaction between Illumination and Passengers. The egress times during the daylight illumination condition for both 17 and 21 passengers were consistent. However, the egress times with 17 passengers in the restricted illumination condition were faster than the daylight condition for either the 17 or 21 passengers. Further, the egress times with 21 passengers in the restricted illumination condition were slower than the daylight condition for either the 17 or 21 passengers. The explanation for this interaction is not immediately apparent and calls for further analysis. One possibility is that there were more snags in the trials with 21 passengers in the restricted illumination condition. Trials in which passengers became snagged resulted in slower egress times.

7. Weapon||Route x Armor||PFD

This significant interaction indicates that egress times are fastest when passengers left their weapons and were able to use the two rear cargo hatches. When they were able to use all five hatches and left their weapons, egress times were unaffected by whether they dropped or wore their body armor and the type of PFD they used. However, when they used just the two cargo hatches, wearing the body armor appeared to slow the egress times more than when they removed it.

As stated previously, the three-hatch conditions (which, in reality, use only the troop commander’s hatch) result in the slowest egress times. Taking weapons slowed egress times even more. And, wearing body armor and taking

weapons resulted in the slowest egress times. These results need to be compared with egress SOPs, training, and doctrine to ensure the Marine Corps is not teaching and enforcing egress procedures that could unnecessarily impede the safe exit from a disabled AAV.

C. RESEARCH QUESTION TWO

The second question asked, “Is the design of experiment appropriate given the safety constraints?” The short answer is “yes.” The researchers took into consideration the factors the sponsors wanted to examine, the safety constraints imposed on the study, and the Marine Corps SOPs and training manuals that addressed egress from an AAV. The result was a full factorial design, which resulted in 72 unique trials, each of which was completed three times for a total of 216 trials over just an eight-day period. This research would not have been possible without the highly motivated Marines who volunteered to participate in the study.

These experimental results provide a baseline for all future egress studies because they were performed under near optimal conditions. It is highly unlikely that Marines would be able to egress from a damaged AAV on land or sea faster than the subjects in this study. Therefore, the results of this study should not be used to guide design or doctrine. Instead, we advocate considering some of the factors that were not present in this study that would have a significant impact on egress from an AAV.

- Vehicle orientation (and Marine Disorientation)–Is the vehicle nose up or down? Is the vehicle on its side or upside down?
- Injuries–Are any Marines injured? If so, how many and how badly?
- Land or Sea–If on land, Marines may have to climb down from the top of the AAV, which will take additional time. If at sea, is there another AAV nearby to assist with egress? Is the AAV taking on water? How fast? Even a little water will impede egress significantly.

- Anthropometry–Will all Marines fit through all hatches when wearing body armor and carrying a weapon? AAVs were built over forty years ago when Marines were smaller in stature and girth and carried much less equipment. In this study, the two largest Marines became snagged frequently. On multiple occasions, a HESP inflated and the Marine became lodged in the hatch. He could not go up or down, effectively trapping everyone behind him.
- Lung Capacity–How long can a Marine hold his or her breath? The egress times in this study ranged from approximately 30 seconds to more than six minutes. If a vehicle has taken on water a HESP only provides a few breaths of air–not enough to sustain most people for six minutes.
- Stress–Are the Marines taking fire? A damaged vehicle in a hostile environment will raise stress levels, which will result in the production of adrenalin. This will help Marines respond to the situation but, in a sinking AAV, it will lead to faster energy expenditure.

D. RESEARCH QUESTION THREE

The third research question asks, “Does the current SOP establish the conditions that will optimize survivability of the subjects and their equipment during waterborne operations?” This question can be answered by comparing the results of this study to the Marine Corps SOPs that address egress procedures. Assault Amphibian School Battalion Order (BNO) P3000.1H is the most recent published common SOP.

Appendix J of the SOP describes the embarked troop brief (ETB) to be given by the vehicle commander. The ETB is a one-page script that is to be read by the vehicle commander prior to waterborne operations. The script states that each passenger must adhere to the crew’s instructions during operations and that understanding the emergency procedures is incumbent on each individual.

The instruction is proved to increase subject awareness and reduce confusion and minimize egress time. The script also requires passengers to familiarize themselves with the pocket sized ETB. However, the SOP only requires one copy per AAV.

The ETB describes the conditions of both the rapid and slow sink scenarios. The responsibility to determine which scenario is unfolding falls to the vehicle commander at which time he commands either "Egress, Egress, Egress" or "Evac, Evac, Evac," which is then echoed by the third crewman. The potential problem with the commands is that both sound similar and evoke the need to exit the vehicle rapidly regardless of the actual situation.

In a slow sink scenario, crew and passengers should gather their equipment and transfer to the recovery vehicle in an orderly manner. However, the SOP makes no mention whether the vehicle commander has the discretion to order the passengers to drop their body armor and leave weapons if he believes the amount of water entering the vehicle may change the situation to a rapid sink scenario.

The ETB does not mention dropping body armor during rapid sink scenarios. As seen in this study, while designated personnel open the cargo hatches, remaining personnel could drop their body armor, which would reduce the possibility of snags, decrease the profile of each individual and lower egress times. The ETB also only mentions egress through the cargo hatches. In recent incidents involving sinking AAVs, subjects egressed from either the forward hatches or the troop hatch located in the ramp (see Appendix H for picture). Post-experiment surveys revealed difficulty opening the cargo hatches on several trials. There was nothing mechanically wrong with the hatches. They simply are heavy and require a relatively tall person to exert considerable force in an upward direction. These cargo hatches would undoubtedly become more cumbersome in rough seas or with a pitched vehicle. The Marine Corps should consider modifying the EBT to include multiple alternate egress routes during an emergency.

In this study, the SOP's guidance for load planning was followed closely throughout the experiment. Figure 38 gives the position for passengers' packs inside the troop compartment.

Figure 38. Load Plan for AAV during waterborne operations

Post-experiment surveys indicated that the packs provided additional footing while egressing through the cargo hatches. However, when passengers had to egress through the forward hatches, the packs became obstacles and snag points. Further, when a vehicle begins to sink it will dive nose first. If the packs were to become unsecured, it would further restrict passengers from moving forward or the driver, troop commander, and vehicle commander from moving to the rear should any individual hatch become inoperable. With no alternative location to stow the packs, it is crucial that the packs are secured tightly and their profile is reduced as much as possible. The ETB emphasize the importance of proper gear storage as it relates to egress.

In summary, the SOP provides the basic information on emergency egress procedures. However, additional information should be added for both the vehicle commander and the passengers so they fully understand what to do across the full spectrum of emergency egress scenarios. The final chapter of this thesis will provide conclusions and propose recommendations for further research.

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VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The present study afforded researchers a rare opportunity to conduct a full factorial experiment under controlled conditions with highly motivated subjects who are representative of the target population. As reported in the previous chapter, several of the factors proved to be statistically significant. However, the results must be considered within the context and manner in which the data were collected. The experiment was conducted in a safe, administrative setting rather than a potentially dangerous field or waterborne environment. Even so, we believe many of these findings to have practical and militarily important implications.

- The more Marines put into the back of the AAV, the longer it will take for them to egress from the vehicle. The increase in time is due not only to the number of personnel but also to their equipment. The more tightly the Marines are crammed into the AAV, the less room each will have to maneuver.
- Wearing body armor will increase egress times.
- Taking weapons will increase egress times.
- Marines at the 95^{th} percentile for girth-type measurements (e.g., chest circumference, shoulder circumference, bideltoid breadth) are more likely to become snagged and, as a result, delay or prevent the egress of those Marines behind them.
- Wearing the LPU-41/SRU-43 HESP will increase the likelihood of becoming snagged during egress (because it is worn over body armor).
- Using the driver's hatch and the crew chief's hatch to egress from the AAV is not viable (except for the driver and crew chief).

Time is critical when Marines are egressing under emergency conditions (e.g., the AAV is sinking or under fire). Seconds matter. Any delay could result in the death of a Marine. Every consideration should be given to the findings of this

study; they should be applied to the re-design of the AAV, the design of the forthcoming ACV, and the SOPs that describe the procedures Marines will use when they egress.

B. RECOMMENDATIONS

The Marine Corps plays a vital role in national security. That role is likely to expand as the U.S. national security policy places greater emphasis in the Pacific Theater. The Marines will continue to need a viable vehicle to transport personnel and equipment from ship to an opposed shore and then to continue the fight inland. A well-designed vehicle will, among other things, facilitate safe and swift egress during emergencies. The findings of this study suggest several areas for additional research and other activities that could improve egress.

Additional studies should be undertaken in operational (rather than administrative) settings. While such studies increase the risk to research subjects, they will more closely approximate the actual conditions Marines would face in combat. These additional studies should be conducted both on land and in water. They should include conditions in which the vehicle is oriented in attitudes representative of tactical situations. The Marine Corps should also consider altering its selection criteria for infantry who will be transported in amphibious vehicles. Marines who exceed the 95th percentile pose a danger to themselves and others during egress. Alternatively, designers of future vehicles must consider the relevant anthropometric measures of the entire infantry population and build a vehicle in which egress is not impeded for Marines of any size. Finally, SOPs should be carefully examined (and revised if necessary) in light of this study to ensure they set the conditions for swift and safe egress. Issues to consider include: when weapons and armor should be taken or dropped; what personal floatation device should be used and how it should be worn; and, which hatches should be used and which should be avoided.

APPENDIX A. AMPHIBIOUS ASSAULT SHIPS - LHA/LHD/LHA(R)

Description

The largest of all amphibious warfare ships; resembles a small aircraft carrier; capable of Vertical/Short Take-Off and Landing (V/STOL), Short Take-Off Vertical Landing (STOVL), Vertical Take-Off and Landing (VTOL) tilt-rotor and Rotary Wing (RW) aircraft operations; contains a well deck to support use of Landing Craft, Air Cushioned (LCAC) and other watercraft (with exception of the first two LHA(R) class ships, LHA 6 and LHA 7, which have no well deck). LHA 8 will feature a well deck.

General Characteristics, LHA(R) Class LHA (6)

Builder: Huntington Ingalls Industries Inc., Ingalls Operations, Pascagoula, Miss.

Date Deployed: Scheduled for delivery to the fleet in 2013.

Propulsion: Two marine gas turbines, two shafts, 70,000 total brake horsepower, two 5,000 horsepower auxiliary propulsion motors.

Length: 844 feet (257.3 meters).

Beam: 106 feet (32.3 meters).

Displacement: Approximately 44,971 long tons full load (45,695 metric tons).

Speed: 20+ knots.

Crew: 1,059 (65 officers)

Load: 1,687 troops (plus 184 surge).

Armament: Two RAM launchers; two NATO Sea Sparrow launchers (with Evolved Sea Sparrow Missile (ESSM)); two 20mm Phalanx CIWS mounts; seven twin .50 cal. machine guns.

Aircraft: A mix of: F-35B Joint Strike Fighters (JSF) STOVL aircraft; MV-22 Osprey VTOL tiltrotors; CH-53E Sea Stallion helicopters; UH-1Y Huey helicopters; AH-1Z Super Cobra helicopters; MH-60S Seahawk helicopters.

Homeport: PCU America (LHA 6), No homeport - under construction; PCU Tripoli (LHA 7), No homeport, under construction.

Ships:

PCU America (LHA6), No homeport - Under Construction

General Characteristics, Wasp Class

Builder: Northrop Grumman Ship Systems Ingalls Operations, Pascagoula, MS.

Date Deployed: July 29, 1989 (USS Wasp)

Propulsion: (LHDs 17) two boilers, two geared steam turbines, two shafts, 70,000 total brake horsepower; (LHD 8) two gas turbines, two shafts; 70,000 total shaft horsepower, two 5,000 horsepower auxiliary propulsion motors.

Length: 844 feet (253.2 meters).

Beam: 106 feet (31.8 meters).

Displacement: LHDs 1-4: 40,650 tons full load (41,302.3 metric tons)

LHDs 5-7: 40,358 tons full load (41,005.6 metric tons)

LHD 8: 41,772 tons full load (42,442.3 metric tons).

Speed: 20+ knots (23.5+ miles per hour).

Crew: Ships Company: 66 officers, 1,004 enlisted

LHD 8: 65 officers, 994 enlisted

Marine Detachment: 1,687 troops (plus 184 surge).

Armament: Two RAM launchers; two NATO Sea Sparrow launchers; three 20mm Phalanx CIWS mounts (two on LHD 5-8); four .50 cal. machine guns; four 25 mm Mk 38 machine guns (LHD 5-8 have three 25 mm Mk 38 machine guns).

Aircraft: 12 CH-46 Sea Knight helicopters; 4 CH-53E Sea Stallion helicopters; 6 AV-8B Harrier attack aircraft; 3 UH-1N Huey helicopters; 4 AH-1W Super Cobra helicopters. (planned capability to embark MV-22 Osprey VTOL tilt-rotors).

Landing/Attack Craft: 3 LCACs or 2 LCUs.

Ships:

USS Wasp (LHD 1), Norfolk, VA

USS Essex (LHD 2), Sasebo, Japan

USS Kearsarge (LHD 3), Norfolk, VA

USS Boxer (LHD 4), San Diego, CA
USS Bataan (LHD 5), Norfolk, VA
USS Bonhomme Richard (LHD 6), San Diego, CA
USS Iwo Jima (LHD 7), Norfolk, VA
USS Makin Island (LHD 8), San Diego, CA

General Characteristics, Tarawa Class
Builder: Ingalls Shipbuilding, Pascagoula, MS.
Date Deployed: May 29, 1976 (USS Tarawa)
Propulsion: Two boilers, two geared steam turbines, two shafts, 70,000 total shaft horsepower.
Length: 820 feet (249.9 meters).
Beam: 106 feet (31.8 meters).
Displacement: 39,400 tons (40,032 metric tons) full load.
Speed: 24 knots (27.6 miles per hour).
Crew: Ships Company: 82 officers, 882 enlisted
Marine Detachment 1,900 plus.
Armament: Two RAM launchers; two Phalanx 20 mm CIWS mount; three .50 cal. machine guns; four 25 mm Mk 38 machine guns.
Aircraft: 12 CH-46 Sea Knight helicopters; 4 CH-53E Sea Stallion helicopters; 6 AV-8B Harrier attack aircraft; 3 UH-1N Huey helicopters; 4 AH-1W Super Cobra helicopters.
Landing/Attack Craft: 4 LCUs or 2 LCUs and 1 LCAC.
Ships:
USS Nassau (LHA 4), Norfolk, VA
USS Peleliu (LHA 5), San Diego, CA

(Amphibious Assault Ships, 2012)

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APPENDIX B. SEA STATES

Table 30. Annual Sea State Occurrences in the Open Ocean North Pacific (from Bales, 1982)

Sea State Number	Significant Wave Height (m)		Sustained Wind Speed (Knots)*		Percentage Probability of Sea State	Modal Wave Period (Sec)	
	Range	Mean	Range	Mean		Range**	Most Probable***
0 - 1	0 - 0.1	0.05	0 - 6	3	0	–	–
2	0.1 - 0.5	0.3	7 - 10	8.5	4.1	3.0 - 15.0	7.5
3	0.5 - 1.25	0.88	11 - 16	13.5	16.9	5.2 - 15.5	7.5
4	1.25 - 2.5	1.88	17 - 21	19	27.8	5.9 - 15.5	8.8
5	2.5 - 4	3.25	22 - 27	24.5	23.5	7.2 - 16.5	9.7
6	4 - 6	5	23 - 47	37.5	16.3	9.3 - 16.5	13.8
7	6 - 9	7.5	48 - 55	51.5	9.1	10.0 - 17.2	13.8
8	9 - 14	11.5	56 - 63	59.5	2.2	13.0 - 18.4	18.0
>8	>14	>14	>63	>63	0.1	20.0	20.0

*Ambient wind sustained at 19.5 m above surface to generate fully-developed seas. To convert to another altitude, H_2, apply $V_2 = V_1(H_2/19.5)^{1/7}$

**Minimum is 5 percentile and maximum is 95 percentile for periods given wave height range.

***Based on periods associated with central frequencies included in Hindcast Climatology.

Table 31. Annual Sea State Occurrences in the Open Ocean Northern Hemisphere (from Bales, 1982)

Sea State Number	Significant Wave Height (m)		Sustained Wind Speed (Knots)*		Percentage Probability of Sea State	Modal Wave Period (Sec)	
	Range	Mean	Range	Mean		Range**	Most Probable
0 - 1	0 - 0.1	0.05	0 - 6	3	0	—	—
2	0.1 - 0.5	0.3	7 - 10	8.5	5.7	3 - 15	7
3	0.5 - 1.25	0.88	11 - 16	13.5	19.7	5 - 15.5	8
4	1.25 - 2.5	1.88	17 - 21	19	28.3	6 - 16	9
5	2.5 - 4	3.25	22 - 27	24.5	19.5	7 - 16.5	10
6	4 - 6	5	28 - 47	37.5	17.5	9 - 17	12
7	6 - 9	7.5	48 - 55	51.5	7.6	10 - 18	14
8	9 - 14	11.5	56 - 63	59.5	1.7	13 - 19	17
>8	>14	>14	>63	>63	0.1	18 - 24	20

*Ambient wind sustained at 19.5 m above surface to generate fully-developed seas. To convert to another altitude, H_2, apply $V_2 = V_1(H_2/19.5)^{1/7}$

**Minimum is 5 percentile and maximum is 95 percentile for periods given wave height range.

APPENDIX C. AAV DIMENSIONS

Table 32. AAV Dimensions 1971

FMC Corp. LVTP7, 1971				
Crew (28 men)	**Dimensions**		**Performance**	
Commander in weapon station	Weight:	50,350lbs/22,840Kg	Road Speed:	40mph/64kph
Driver in hull left front	Height:	128.5in/326.4cm	Water Speed:	8.4mph/14kph
Assistant driver in hull left center	Length:	312.75in/794.39cm	Land Range:	300mi/480km
Troop commander in hull left front	Width:	128.72in/326.95cm	Water Range:	56mi/90km
24 combat loaded passengers				

(from: American Fighting Vehicle Database, 2013)

Table 33. AAV Dimensions 1983

FMC Corp. AAVP7A1, 1983				
Crew (28 men)	**Dimensions**		**Performance**	
Commander in weapon station	Weight:	56,552lbs/25,652kg	Road Speed:	45mph/72kph
Driver in hull left front	Height:	130.5in/331.5cm	Water Speed:	8.2mph/13kph
Assistant driver in hull left center	Length:	321.3in/816.1cm	Land Range:	300mi/480km
Troop commander in hull left front	Width:	128.72in/326.95cm	Water Range:	56mi/90km
24 combat loaded passengers				

(from: American Fighting Vehicle Database, 2013)

Table 34. AAV Dimensions 1995 - Present

United Defense Limited Partnership Corp. AAVP7A1 (RAM/RS), 1995				
Crew (24 men)	**Dimensions**		**Performance**	
Commander in weapon station	Weight:	58,105lbs/26,356kg	Road Speed:	45mph/72kph
Driver in hull left front	Height:	130.5in/331.5cm	Water Speed:	8.2mph/13kph
Assistant driver in hull left center	Length:	321.3in/816.1cm	Land Range:	300mi/480km
Troop commander in hull left front	Width:	130.6in/331.72cm	Water Range:	56mi/90km
20 combat loaded passengers				

(from: MCWP 3-13, 2005)

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APPENDIX D. AVERAGE ANTHROPOMETRIC MEASUREMENTS

Table 35. Average Anthropometric Measurements (NPS Experiment Team, Camp Pendleton, 2012)

Passenger	PT-Stature	PT-Weight	PT-Shoulder Circumference	PT-Chest Circumfrance	PT-Waist Circumference	PT-Buttock Circumfrance	PT-Chest Depth	PT-Bedeltoid Breadth	Slick-Stature	Slick-Weight	Slick-Shoulder Circumference	Slick-Chest Circumfrance	Slick-Waist Circumference	Slick-Buttock Circumference	Slick-Chest Depth	Slick-Bedeltoid Breadth	CL-Stature	CL-Weight	CL-Shoulder Circumfrance	CL-Chest Circumference	CL-Waist Circumfrance	CL-Buttock Circumference	CL-Chest Depth	CL-Bedeltoid Breadth
1	173.30	166.33	116.55	98.15	82.60	101.90	22.85	47.50	176.20	174.00	120.00	100.10	89.15	103.80	23.00	47.50	180.20	196.33	128.45	117.30	108.60	103.35	32.65	51.55
2	174.73	200.58	126.00	103.90	89.50	114.00	23.95	49.90	180.33	211.00	128.95	107.15	100.10	119.30	24.90	49.90	184.53	234.58	133.55	126.45	115.15	119.90	34.90	53.25
3	176.70	190.00	124.10	102.50	91.50	105.70	22.75	50.20	180.40	197.00	126.55	102.70	96.70	108.25	23.10	50.20	185.63	221.00	135.00	121.35	113.60	109.00	33.60	50.40
4	164.23	169.67	124.50	103.95	87.20	98.30	24.70	55.60	167.40	178.08	131.40	105.70	88.65	103.35	24.65	55.60	171.27	214.08	137.25	126.75	143.50	104.15	39.55	58.50
5	182.10	184.67	122.00	102.25	77.65	102.20	22.75	51.25	185.63	192.75	125.15	101.90	82.00	109.80	23.10	51.25	188.20	228.00	188.85	136.00	131.45	112.05	43.00	55.80
6	177.23	228.25	142.05	123.95	103.10	115.25	27.60	59.25	180.23	237.42	145.90	124.00	105.95	121.25	28.50	59.25	184.03	278.33	158.25	147.25	165.00	121.70	49.30	60.25
7	175.73	155.75	108.20	94.55	79.35	94.70	21.35	45.65	179.67	165.67	115.95	96.05	79.90	103.25	21.40	45.65	184.10	201.00	128.60	120.40	134.25	108.75	43.70	50.55
8	182.33	148.83	110.20	92.05	76.70	97.85	21.15	46.55	186.20	158.00	114.05	91.00	79.50	102.90	21.15	46.55	189.87	197.75	128.10	115.15	151.75	106.60	42.70	49.90
9	161.63	140.00	113.45	97.80	82.25	96.55	24.50	46.65	165.20	149.75	118.65	102.75	87.70	103.50	25.05	46.65	168.00	190.83	134.00	123.10	137.35	104.25	40.80	49.25
10	163.37	139.58	107.90	94.70	80.05	94.10	23.20	43.30	167.33	145.50	109.70	97.05	86.15	103.50	23.30	43.30	171.23	184.83	128.65	137.95	143.00	106.50	40.85	48.00
11	177.83	171.42	124.55	105.75	78.30	99.70	23.45	53.65	180.97	181.50	128.80	107.00	80.00	106.30	23.15	53.65	184.73	220.00	143.65	133.50	147.90	112.80	45.45	56.45
12	174.90	187.83	122.25	106.90	89.60	101.35	26.50	49.30	180.33	197.50	128.85	109.00	96.25	107.00	26.45	49.30	184.50	237.92	141.40	130.25	157.00	110.25	44.60	55.75
13	172.07	162.00	114.70	93.50	78.60	99.50	22.10	48.00	175.43	171.00	119.90	96.80	83.00	105.45	23.15	48.00	177.90	203.42	126.25	122.65	145.85	106.50	40.50	52.75
14	165.43	148.92	117.15	91.15	77.55	91.75	22.15	48.10	169.63	157.00	119.35	93.50	81.00	98.75	21.35	48.10	173.27	190.92	133.75	124.30	139.25	104.55	38.60	51.25
15	163.40	155.25	115.90	94.95	82.45	99.70	21.85	48.95	166.20	162.58	120.65	98.75	85.60	105.65	22.35	48.95	170.27	200.50	135.00	126.25	130.90	111.50	44.65	52.15
16	179.00	196.33	125.15	103.75	85.55	105.15	24.80	51.65	182.97	206.00	126.85	102.50	90.25	114.25	25.65	51.65	187.00	242.67	142.00	126.65	146.35	117.15	38.35	54.50
17	172.67	173.33	126.30	100.35	80.05	99.20	24.20	52.85	176.60	181.83	127.75	99.45	84.10	106.35	23.20	52.85	180.60	222.50	144.00	125.85	150.85	113.95	47.05	55.00
18	173.40	172.42	118.10	97.60	78.20	97.00	23.00	48.25	178.90	183.75	121.15	101.05	81.55	105.50	23.35	48.25	182.07	224.25	136.05	132.60	139.25	107.45	41.75	52.50
19	170.63	160.50	113.65	95.75	81.50	99.20	22.90	47.75	176.37	170.75	119.00	97.95	84.40	106.45	22.85	47.75	178.37	210.17	133.25	124.25	141.80	109.85	41.25	52.75
20	175.63	239.42	131.90	123.95	106.70	115.25	28.35	55.75	179.20	249.00	152.75	122.40	110.00	122.35	29.60	55.75	183.53	292.00	144.50	143.85	157.10	124.00	47.85	60.10
21	168.00	183.25	125.10	109.20	84.30	100.65	25.90	53.00	169.37	190.33	130.30	109.30	89.60	108.55	26.65	53.00	173.77	222.83	135.25	130.80	142.50	108.05	47.80	56.35
22	178.53	187.32	117.25	99.80	84.10	101.00	23.85	49.35	181.13	193.67	121.05	102.10	90.10	109.10	24.40	49.35	186.40	236.25	136.40	128.35	135.10	113.25	44.70	51.85
23	164.73	147.25	115.35	95.70	76.70	96.60	24.05	47.35	167.53	156.67	120.65	96.25	79.15	105.05	23.95	47.35	171.50	193.25	131.00	118.50	140.60	105.00	38.85	50.85
24	183.03	179.83	118.90	103.00	84.85	105.60	24.60	48.10	186.80	189.50	124.40	103.60	86.75	110.45	24.30	48.10	190.40	226.00	142.25	136.60	139.90	110.80	41.80	53.10
25	175.20	164.92	121.45	101.40	77.65	99.05	23.35	50.30	179.40	172.67	125.95	104.25	82.00	102.90	24.05	50.30	181.93	215.42	137.45	130.30	142.00	109.90	47.40	52.30
26	183.40	175.00	117.00	98.20	84.00	100.85	23.95	50.25	188.30	184.50	123.95	100.60	85.05	110.00	23.30	50.25	190.30	226.08	134.15	136.70	149.45	112.60	38.15	52.00

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APPENDIX E. EQUIPMENT LIST

Table 36. Equipment List

NPS Team Equipment List		
Perishable Items	**Lab Items Needed on Site**	**Optional Personal Items to Bring**
Sticky Notes	DVD Video Camera/Tripod	Sun screen!!
Sharpie Markers	Recordable DVD	Lawn Chairs
9 volt, AA, and AAA	Extensions cords	Rugged shoes
Clipboards	30 Actiwatches	Jeans or work khakis
Duct tape	3 Actiwatch computers	Work Shirt for weather
Pens/Pencils	2 old readers	Snacks for you
Document folders	Batteries for Actiwatch	Snacks for the Marines!
Scissors	Screw Driver for Actiwatch	A hat
Burnable CD’s	Chargers for Laptops	Notebook/Pen/Pencil/Computer
	Adaptors for various laptops	
	Sleep logs and Envelopes	
	Digital Voice Recorders- 10	
	Anthropometry measuring devices	

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APPENDIX F. ATTACHED RUN MATRIX

6-Aug-12						
Time	**Event**	**Who**	**Where**		**Special Instructions**	
5:30	Chow	Participants	Camp Horno			
6:00	Load Buses	Participants	Horno Grinder			
7:00	Prep Test Area	AVTB/NPS	AVTB Test Site		All research personnel on site	
7:00	Buses arrive	Participants	AVTB Test Site			
7:30	Morning report	Participants	AVTB Test Site		Safety Brief	
8:00	In-brief	All Hands	AVTB Test Site			
8:30	Collect data	All Hands	AVTB Test Site		Station Rotaion	
	Familiarization I		**Lighting**	**Embarked**	**Ensemble**	**Weapon/Route**
10:00			Day	17	E1	L5
10:12			Day	17	E2	L3
10:24			Day	17	E3	L2
10:36			Day	21	E1	T4
10:48			Day	21	E2	T3
11:00			Day	21	E3	T1
11:12	Chow					
11:12	Prep Test Area	AVTB/NPS				
12:30	Return	All Hands				
	Familiarization II		**Lighting**	**Embarked**	**Ensemble**	**Weapon/Route**
13:00			Night	17	E1	T4
13:15			Night	17	E2	T3
13:30			Night	17	E3	T1
13:45			Night	21	E1	L5
14:00			Night	21	E2	L3
14:15			Night	21	E3	L2
14:30	Hotwash	All Hands	Test Site		Will go at conclusion of	
14:50	Return Weapons	Participants	3d AAV Bn Armory		last run	
14:50	Team AAR	AVTB/NPS	Test Site			
16:30	Buses Launch	Participants	21 Area			

Note: **PFD = Personnel Flotation Device**

E1-Armor worn / PFD 1a
E2-Armor worn / PFD HESP
E3-Armor off / PFD 1a

L5 - leave weapon / any hatch
L2 - leave weapon / cargo hatch only
L3 - leave weapon / forward hatches only
T4 - take weapon / any hatch
T1 - take weapon / cargo hatch only
T3 - take weapon / forward hatches only

7-Aug-12							
Time	**Event**	**Who**	**Where**		**Special Instructions**		
5:30	Chow	Participants	Camp Horno				
6:30	Buses Launch	Participants	Horno Grinder				
7:00	Prep Test Area	AVTB/NPS	AVTB Test Site		All research personnel on site		
7:15	Buses arrive	Participants	AVTB Test Site				
7:30	Morning report	Participants	AVTB Test Site		Safety Brief		
	BLOCK I	**Run Number**	**Lighting**	**Embarked**	**Ensemble**	**Weapon/Route**	
8:00		1	Day	17	E3	L5	
8:12		2	Day	17	E1	L2	
8:24		3	Day	17	E2	L2	
8:36		4	Day	17	E2	T4	
8:48		5	Day	17	E3	T3	
9:00	Break						
9:10		6	Day	17	E2	L3	
9:22		7	Day	17	E1	L5	
9:34		8	Day	17	E2	L5	
9:46		9	Day	17	E2	T1	
9:58		10	Day	17	E3	T1	
10:10	Break						
10:20		11	Day	17	E2	T3	
10:32		12	Day	17	E1	L3	
10:44		13	Day	17	E3	T4	
10:56		14	Day	17	E3	L2	
11:08	Chow	Participants					
10:56	Prep Test Area	AVTB/NPS					
12:30	Return	All Hands					
	BLOCK II	**Run Number**	**Lighting**	**Embarked**	**Ensemble**	**Weapon/Route**	
13:00		15	Night	21	E3	L5	
13:12		16	Night	21	E1	L2	
13:24		17	Night	21	E2	L2	
13:36		18	Night	21	E2	T4	
13:48		19	Night	21	E3	T3	
14:00	Break						
14:10		20	Night	21	E2	L3	
14:22		21	Night	21	E1	L5	
14:34		22	Night	21	E2	L5	
14:46		23	Night	21	E2	T1	
14:58		24	Night	21	E3	T1	
15:08	Break						
15:20		25	Night	21	E2	T3	
15:32		26	Night	21	E1	L3	
15:44		27	Night	21	E3	T4	
15:56	Hotwash	All Hands	Test Site		Will go at conclusion of last run		
16:06	Team AAR	AVTB/NPS	Test Site				
16:30	Buses Launch	Participants	21 Area				

8-Aug-12							
Time	**Event**	**Who**	**Where**		**Special Instructions**		
5:30	Chow	Participants	Camp Horno				
6:30	Buses Launch	Participants	Horno Grinder				
7:00	Prep Test Area	AVTB/NPS	AVTB Test Site		All research personnel on site		
7:15	Buses arrive	Participants	AVTB Test Site				
7:30	Morning report	Participants	AVTB Test Site		Safety Brief		
	BLOCK I	**Run Number**	**Lighting**	**Embarked**	**Ensemble**	**Weapon/Route**	
8:00		28	Night	21	E3	L2	
8:12		29	Night	21	E1	T1	
8:24		30	Night	21	E3	L3	
8:36		31	Night	21	E1	T4	
8:48		32	Night	21	E1	T3	
9:00	Break						
9:10		33	Night	21	E3	L5	
9:22		34	Night	21	E1	L2	
9:34		35	Night	21	E2	L2	
9:46		36	Night	21	E2	T4	
9:58		37	Night	21	E3	T3	
10:10	Break						
10:20		38	Night	21	E2	L3	
10:32		39	Night	21	E1	L5	
10:44		40	Night	21	E2	L5	
10:56		41	Night	21	E2	T1	
11:08	Chow	Participants					
10:56	Prep Test Area	AVTB/NPS					
12:30	Return	All Hands					
	BLOCK II	**Run Number**	**Lighting**	**Embarked**	**Ensemble**	**Weapon/Route**	
13:00		42	Day	17	E1	T1	
13:12		43	Day	17	E3	L3	
13:24		44	Day	17	E1	T4	
13:36		45	Day	17	E1	T3	
13:48		46	Day	17	E3	L5	
14:00	Break						
14:10		47	Day	17	E1	L2	
14:22		48	Day	17	E2	L2	
14:34		49	Day	17	E2	T4	
14:46		50	Day	17	E3	T3	
14:58		51	Day	17	E2	L3	
15:08	Break						
15:20		52	Day	17	E1	L5	
15:32		53	Day	17	E2	L5	
15:44		54	Day	17	E2	T1	
15:56	Hotwash	All Hands	Test Site		Will go at conclusion of last run		
16:06	Team AAR	AVTB/NPS	Test Site				
16:30	Buses Launch	Participants	21 Area				

9-Aug-12							
Time	**Event**	**Who**	**Where**		**Special Instructions**		
5:30	Chow	Participants	Camp Horno				
6:30	Buses Launch	Participants	Horno Grinder				
7:00	Prep Test Area	AVTB/NPS	AVTB Test Site		All research personnel on site		
7:15	Buses arrive	Participants	AVTB Test Site				
7:30	Morning report	Participants	AVTB Test Site		Safety Brief		
	BLOCK I	**Run Number**	**Lighting**	**Embarked**	**Ensemble**	**Weapon/Route**	
8:00		55	Day	21	E3	L5	
8:12		56	Day	21	E1	L2	
8:24		57	Day	21	E2	L2	
8:36		58	Day	21	E2	T4	
8:48		59	Day	21	E3	T3	
9:00	Break						
9:10		60	Day	21	E2	L3	
9:22		61	Day	21	E1	L5	
9:34		62	Day	21	E2	L5	
9:46		63	Day	21	E2	T1	
9:58		64	Day	21	E3	T1	
10:10	Break						
10:20		65	Day	21	E2	T3	
10:32		66	Day	21	E1	L3	
10:44		67	Day	21	E3	T4	
10:56		68	Day	21	E3	L2	
11:08	Chow						
10:56	Prep Test Area	AVTB/NPS					
12:30	Return	All Hands					
	BLOCK II	**Run Number**	**Lighting**	**Embarked**	**Ensemble**	**Weapon/Route**	
13:00		69	Night	17	E3	L5	
13:12		70	Night	17	E1	L2	
13:24		71	Night	17	E2	L2	
13:36		72	Night	17	E2	T4	
13:48		73	Night	17	E3	T3	
14:00	Break						
14:10		74	Night	17	E2	L3	
14:22		75	Night	17	E1	L5	
14:34		76	Night	17	E2	L5	
14:46		77	Night	17	E2	T1	
14:58		78	Night	17	E3	T1	
15:08	Break						
15:20		79	Night	17	E2	T3	
15:32		80	Night	17	E1	L3	
15:44		81	Night	17	E3	T4	
15:56	Hotwash	All Hands	Test Site		Will go at conclusion of last run		
16:06	Team AAR	AVTB/NPS	Test Site				
16:30	Buses Launch	Participants	21 Area				

10-Aug-12							
Time	**Event**	**Who**	**Where**		**Special Instructions**		
5:30	Chow	Participants	Camp Horno				
6:30	Buses Launch	Participants	Horno Grinder				
7:00	Prep Test Area	AVTB/NPS	AVTB Test Site		All research personnel on site		
7:15	Buses arrive	Participants	AVTB Test Site				
7:30	Morning report	Participants	AVTB Test Site		Safety Brief		
	BLOCK I	**Run Number**	**Lighting**	**Embarked**	**Ensemble**	**Weapon/Route**	
8:00		82	Night	17	E3	L2	
8:12		83	Night	17	E1	T1	
8:24		84	Night	17	E3	L3	
8:36		85	Night	17	E1	T4	
8:48		86	Night	17	E1	T3	
9:00	Break						
9:10		87	Night	17	E3	L5	
9:22		88	Night	17	E1	L2	
9:34		89	Night	17	E2	L2	
9:46		90	Night	17	E2	T4	
9:58		91	Night	17	E3	T3	
10:10	Break						
10:20		92	Night	17	E2	L3	
10:32		93	Night	17	E1	L5	
10:44		94	Night	17	E2	L5	
10:56		95	Night	17	E2	T1	
11:08	Chow	Participants					
10:56	Prep Test Area	AVTB/NPS					
12:30	Return	All Hands					
	BLOCK II	**Run Number**	**Lighting**	**Embarked**	**Ensemble**	**Weapon/Route**	
13:00		96	Day	21	E1	T1	
13:12		97	Day	21	E3	L3	
13:24		98	Day	21	E1	T4	
13:36		99	Day	21	E1	T3	
13:48		100	Day	21	E3	L5	
14:00	Break						
14:10		101	Day	21	E1	L2	
14:22		102	Day	21	E2	L2	
14:34		103	Day	21	E2	T4	
14:46		104	Day	21	E3	T3	
14:58		105	Day	21	E2	L3	
15:08	Break						
15:20		106	Day	21	E1	L5	
15:32		107	Day	21	E2	L5	
15:44		108	Day	21	E2	T1	
15:56	Hotwash	All Hands	Test Site		Will go at conclusion of last run		
16:06	Team AAR	AVTB/NPS	Test Site				
16:30	Buses Launch	Participants	21 Area				

13-Aug-12						
Time	**Event**	**Who**	**Where**		**Special Instructions**	
5:30	Chow	Participants	Camp Horno			
6:30	Buses Launch	Participants	Horno Grinder			
7:00	Prep Test Area	AVTB/NPS	AVTB Test Site		All research personnel on site	
7:15	Buses arrive	Participants	AVTB Test Site			
7:30	Morning report	Participants	AVTB Test Site		Safety Brief	
	BLOCK I	**Run Number**	**Lighting**	**Embarked**	**Ensemble**	**Weapon/Route**
8:00		109	Day	17	E3	T1
8:12		110	Day	17	E2	T3
8:24		111	Day	17	E1	L3
8:36		112	Day	17	E3	T4
8:48		113	Day	17	E3	L2
9:00	Break					
9:10		114	Day	17	E1	T1
9:22		115	Day	17	E3	L3
9:34		116	Day	17	E1	T4
9:46		117	Day	17	E1	T3
9:58		118	Day	17	E3	L5
10:10	Break					
10:20		119	Day	17	E1	L2
10:32		120	Day	17	E2	L2
10:44		121	Day	17	E2	T4
10:56		122	Day	17	E3	T3
11:08	Chow	Participants				
10:56	Prep Test Area	AVTB/NPS				
12:30	Return	All Hands				
	BLOCK II	**Run Number**	**Lighting**	**Embarked**	**Ensemble**	**Weapon/Route**
13:00		123	Night	21	E3	T1
13:12		124	Night	21	E2	T3
13:24		125	Night	21	E1	L3
13:36		126	Night	21	E3	T4
13:48		127	Night	21	E3	L2
14:00	Break					
14:10		128	Night	21	E1	T1
14:22		129	Night	21	E3	L3
14:34		130	Night	21	E1	T4
14:46		131	Night	21	E1	T3
14:58		132	Night	21	E3	L5
15:08	Break					
15:20		133	Night	21	E1	L2
15:32		134	Night	21	E2	L2
15:44		135	Night	21	E2	T4
15:56	Hotwash	All Hands	Test Site		Will go at conclusion of last run	
16:06	Team AAR	AVTB/NPS	Test Site			
16:30	Buses Launch	Participants	21 Area			

14-Aug-12							
Time	**Event**	**Who**	**Where**		**Special Instructions**		
5:30	Chow	Participants	Camp Horno				
6:30	Buses Launch	Participants	Horno Grinder				
7:00	Prep Test Area	AVTB/NPS	AVTB Test Site		All research personnel on site		
7:15	Buses arrive	Participants	AVTB Test Site				
7:30	Morning report	Participants	AVTB Test Site		Safety Brief		
	BLOCK I	**Run Number**	**Lighting**	**Embarked**	**Ensemble**	**Weapon/Route**	
8:00		136	Night	21	E3	T3	
8:12		137	Night	21	E2	L3	
8:24		138	Night	21	E1	L5	
8:36		139	Night	21	E2	L5	
8:48		140	Night	21	E2	T1	
9:00	Break						
9:10		141	Night	21	E3	T1	
9:22		142	Night	21	E2	T3	
9:34		143	Night	21	E1	L3	
9:46		144	Night	21	E3	T4	
9:58		145	Night	21	E3	L2	
10:10	Break						
10:20		146	Night	21	E1	T1	
10:32		147	Night	21	E3	L3	
10:44		148	Night	21	E1	T4	
10:56		149	Night	21	E1	T3	
11:08	Chow	Participants					
10:56	Prep Test Area	AVTB/NPS					
12:30	Return	All Hands					
	BLOCK II	**Run Number**	**Lighting**	**Embarked**	**Ensemble**	**Weapon/Route**	
13:00		150	Day	17	E2	L3	
13:12		151	Day	17	E1	L5	
13:24		152	Day	17	E2	L5	
13:36		153	Day	17	E2	T1	
13:48		154	Day	17	E3	T1	
14:00	Break						
14:10		155	Day	17	E2	T3	
14:22		156	Day	17	E1	L3	
14:34		157	Day	17	E3	T4	
14:46		158	Day	17	E3	L2	
14:58		159	Day	17	E1	T1	
15:08	Break						
15:20		160	Day	17	E3	L3	
15:32		161	Day	17	E1	T4	
15:44		162	Day	17	E1	T3	
15:56	Hotwash	All Hands	Test Site		Will go at conclusion of last run		
16:06	Team AAR	AVTB/NPS	Test Site				
16:30	Buses Launch	Participants	21 Area				

15-Aug-12							
Time	**Event**	**Who**	**Where**		**Special Instructions**		
5:30	Chow	Participants	Camp Horno				
6:30	Buses Launch	Participants	Horno Grinder				
7:00	Prep Test Area	AVTB/NPS	AVTB Test Site		All research personnel on site		
7:15	Buses arrive	Participants	AVTB Test Site				
7:30	Morning report	Participants	AVTB Test Site		Safety Brief		
	BLOCK I	**Run Number**	**Lighting**	**Embarked**	**Ensemble**	**Weapon/Route**	
8:00		163	Day	21	E3	T1	
8:12		164	Day	21	E2	T3	
8:24		165	Day	21	E1	L3	
8:36		166	Day	21	E3	T4	
8:48		167	Day	21	E3	L2	
9:00	Break						
9:10		168	Day	21	E1	T1	
9:22		169	Day	21	E3	L3	
9:34		170	Day	21	E1	T4	
9:46		171	Day	21	E1	T3	
9:58		172	Day	21	E3	L5	
10:10	Break						
10:20		173	Day	21	E1	L2	
10:32		174	Day	21	E2	L2	
10:44		175	Day	21	E2	T4	
10:56		176	Day	21	E3	T3	
11:08	Chow						
10:56	Prep Test Area	AVTB/NPS					
12:30	Return	All Hands					
	BLOCK II	**Run Number**	**Lighting**	**Embarked**	**Ensemble**	**Weapon/Route**	
13:00		177	Night	17	E3	T1	
13:12		178	Night	17	E2	T3	
13:24		179	Night	17	E1	L3	
13:36		180	Night	17	E3	T4	
13:48		181	Night	17	E3	L2	
14:00	Break						
14:10		182	Night	17	E1	T1	
14:22		183	Night	17	E3	L3	
14:34		184	Night	17	E1	T4	
14:46		185	Night	17	E1	T3	
14:58		186	Night	17	E3	L5	
15:08	Break						
15:20		187	Night	17	E1	L2	
15:32		188	Night	17	E2	L2	
15:44		189	Night	17	E2	T4	
15:56	Hotwash	All Hands	Test Site		Will go at conclusion of last run		
16:06	Team AAR	AVTB/NPS	Test Site				
16:30	Buses Launch	Participants	21 Area				

16-Aug-12							
Time	**Event**	**Who**	**Where**		**Special Instructions**		
5:30	Chow	Participants	Camp Horno				
6:30	Buses Launch	Participants	Horno Grinder				
7:00	Prep Test Area	AVTB/NPS	AVTB Test Site		All research personnel on site		
7:15	Buses arrive	Participants	AVTB Test Site				
7:30	Morning report	Participants	AVTB Test Site		Safety Brief		
	BLOCK I	**Run Number**	**Lighting**	**Embarked**	**Ensemble**	**Weapon/Route**	
8:00		190	Night	17	E3	T3	
8:12		191	Night	17	E2	L3	
8:24		192	Night	17	E1	L5	
8:36		193	Night	17	E2	L5	
8:48		194	Night	17	E2	T1	
9:00	Break						
9:10		195	Night	17	E3	T1	
9:22		196	Night	17	E2	T3	
9:34		197	Night	17	E1	L3	
9:46		198	Night	17	E3	T4	
9:58		199	Night	17	E3	L2	
10:10	Break						
10:20		200	Night	17	E1	T1	
10:32		201	Night	17	E3	L3	
10:44		202	Night	17	E1	T4	
10:56		203	Night	17	E1	T3	
11:08	Chow						
10:56	Prep Test Area	AVTB/NPS					
12:30	Return	All Hands					
	BLOCK II	**Run Number**	**Lighting**	**Embarked**	**Ensemble**	**Weapon/Route**	
13:00		204	Day	21	E2	L3	
13:12		205	Day	21	E1	L5	
13:24		206	Day	21	E2	L5	
13:36		207	Day	21	E2	T1	
13:48		208	Day	21	E3	T1	
14:00	Break						
14:10		209	Day	21	E2	T3	
14:22		210	Day	21	E1	L3	
14:34		211	Day	21	E3	T4	
14:46		212	Day	21	E3	L2	
14:58		213	Day	21	E1	T1	
15:08	Break						
15:20		214	Day	21	E3	L3	
15:32		215	Day	21	E1	T4	
15:44		216	Day	21	E1	T3	
15:56	Hotwash	All Hands	Test Site		Will go at conclusion of last run		
16:06	Team AAR	AVTB/NPS	Test Site				
16:30	Buses Launch	Participants	21 Area				

17-Aug-12				
Time	**Event**	**Who**	**Where**	**Special Instructions**
				No scheduled runs
				Left open for make up
5:30	Chow	Participants	Camp Horno	
6:30	Buses Launch	Participants	Horno Grinder	
7:00	Prep Test Area	AVTB/NPS	AVTB Test Site	All research personnel on site
7:00	Buses arrive	Participants	AVTB Test Site	
7:30	Morning report	Participants	AVTB Test Site	
8:00	Begin	Participants		

APPENDIX G. POST EXPERIMENT SURVEY

Amphibious Assault Vehicle

Egress Study

Post-Experiment Survey

Administered on

17 August 2012

by

Amphibious Vehicle

Test Branch

and the

Naval Postgraduate School

1. Please enter your participant number:

2. Please check the number that best describes your level of difficulty in GETTING INTO the AAV (select one):

	Very Easy (1)	2	3	Neither Easy nor Hard (4)	5	6	Very Hard (7)
without seatbelts.	○	○	○	○	○	○	○
with seatblets.	○	○	○	○	○	○	○
in daylight conditions.	○	○	○	○	○	○	○
in dark conditions.	○	○	○	○	○	○	○
with 17 Marines (Marines 1 - 20 only).	○	○	○	○	○	○	○
with 21 Marines.	○	○	○	○	○	○	○

3. Please check the number that best describes your level of difficulty in GETTING OUT OF the AAV (select one):

	Very Easy (1)	2	3	Neither Easy nor Hard (4)	5	6	Very Hard (7)
When you had to take your weapon.	○	○	○	○	○	○	○
When you had to leave your weapon.	○	○	○	○	○	○	○
in daylight conditions.	○	○	○	○	○	○	○
in dark conditions.	○	○	○	○	○	○	○
when you wore the personal flotation device over your body armor.	○	○	○	○	○	○	○
when you wore the personal flotation device under your body armor.	○	○	○	○	○	○	○
with 17 Marines (Marine #s 1 - 20 only).	○	○	○	○	○	○	○
with 21 Marines.	○	○	○	○	○	○	○

4. Which condition made it more difficult to exit the AAV?

○ Daylight

○ Dark

○ About the same

5. Which condition made it more difficult to exit the AAV?

- ◯ 17 Marines
- ◯ 21 Marines
- ◯ About the same

6. Which condition made it more difficult to exit the AAV?

- ◯ Take the weapon
- ◯ Leave the weapon
- ◯ About the same

7. Which condition made it more difficult to exit the AAV?

- ◯ Keeping armor on
- ◯ Taking armor off
- ◯ About the same

8. Which condition made it more difficult to exit the AAV?

- ◯ Green life vest (LPU-32)
- ◯ Tan life vest (LPU-41)
- ◯ About the same

9. Which condition made it more difficult to exit the AAV?

- ◯ All hatches
- ◯ Forward hatches and rear starboard cargo hatch
- ◯ Forward hatches only
- ◯ Both rear cargo hatches
- ◯ Rear starboard cargo hatch only
- ◯ All hatch combinations were about the same

10. What else made it hard to get out of the AAV?

11. In scenarios where you took off your body armor and left your weapon, what did you do with them? Did your body armor or others' body armor get in the way when you were exiting the AAV?

12. What would have helped you get out of the AAV more quickly?

13. Did the way you exited the hatches change from the first few trials to the last few trials? If so, for what hatches and how did it change?

14. Was there anything (for example, illness, injury, lack of sleep, etc.) that might have affected your performance during the test?

15. Additional Comments:

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APPENDIX H. TEST BAY

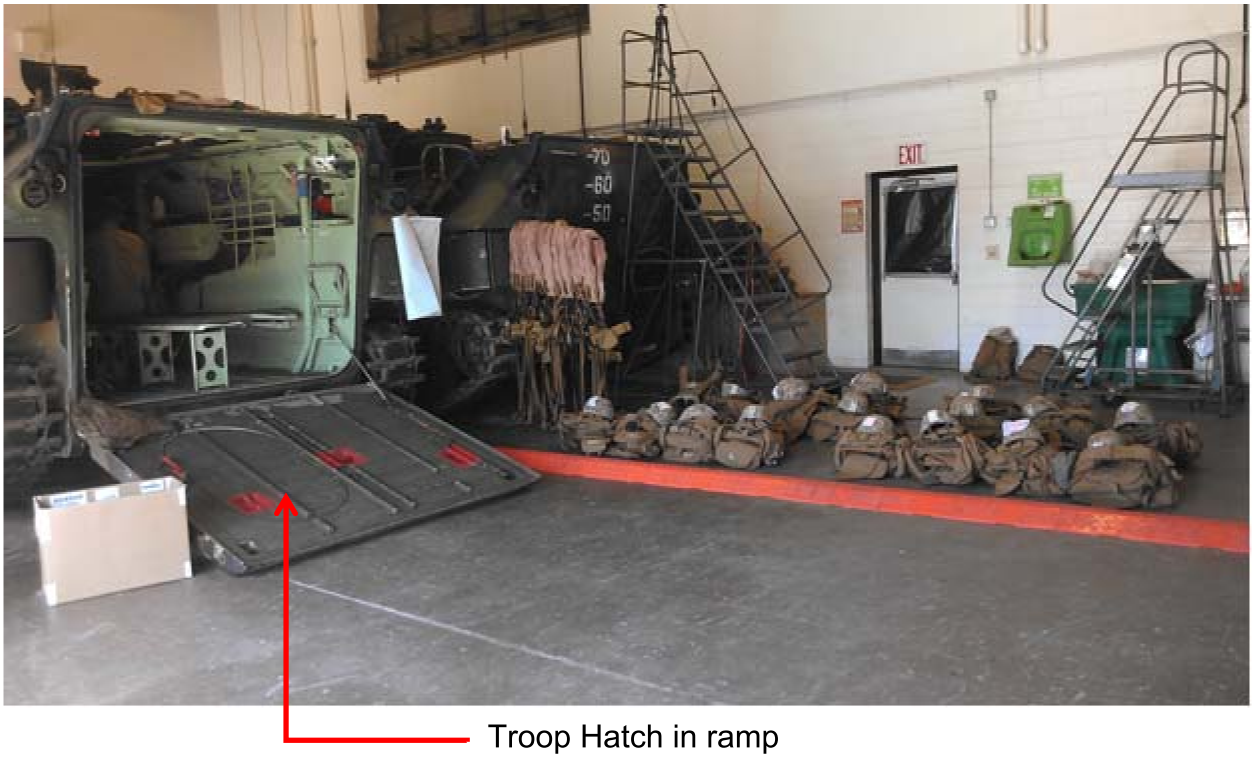

Figure 39. View of test bay

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